Gough Adds. Wales.
8°. 64.

A

# TREATISE

ON THE

# COAL FIELD

OF

# SOUTH WALES,

## EXPLANATORY OF A NEW THEORY

OF THE

## Position of the Measures therein:

WITH

A DEMONSTRATION OF THE SUBSIDENCES INTERVENING LLYNVI AND PENLLERGAER,

*&c., &c., &c.*

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BY FREDERICK MOSES,

MINING ENGINEER, &c.


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"Nor should it escape careful notice that the regulations on which all the laws of matter proceed, are established on a rigidly-accurate mathematical basis."—VESTIGES OF THE NATURAL HISTORY OF CREATION.

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TO THE

LANDED PROPRIETORS, IRON MASTERS,

ETC. ETC. ETC.,

INTERESTED IN THE

COAL FIELD OF SOUTH WALES,

This Treatise

IS RESPECTFULLY DEDICATED

BY

THE AUTHOR.

NEATH, MAY, 1849.

# PREFACE.

THE reception which the first edition of this Treatise met with, together with the solicitations of numerous friends, have induced me to send forth a second, containing, in addition to the subjects treated of in the former, a demonstration of the subsidences which have taken place in the district between Llynvi and Penllergaer, and which may be applied to all the stratified rocks, from the coal measures down to the granite.

The numerous and extensive dislocations which have taken place in the strata in the district alluded to, appear to have hitherto baffled the most experienced and accomplished, in correctly classifying the beds on one side of these subsidences, with those on the other. Indeed, so manifestly does this difficulty present itself to our notice, that it is scarcely possible to find two individuals, geologists or surveyors, who entertain the same opinion respecting them.

I was first led to alter my views relative to the position taken by the strata in the South Welsh Coal Field, whilst prosecuting extensive Surveys in the district between the River Taff on the east, and Swansea Bay on the west; when I found them presenting a form in their transverse or meridional direction, much more resembling an angle

than a curve, and the flexures in the synclinals or inverted bends taking place at right angles to the inclination of the measures, from the outcrop, &c.; but in instances, local and rare in this Coal Field, where the dip of the beds exceeds an angle of 45°, the flexures appear oblique, thus shewing that the maximum folds of the stratification in the synclinals, do not usually surpass a perpendicular to an angle of dip of 45°, and in cases where the inclination of the beds exceeds that angle, the flexures become oblique. After further researches on subsequent occasions, I became fully convinced of the correctness of my views, which were ultimately reduced to a theory, by which a calculation could be made with a degree of marked accuracy, of the position occupied by any particular stratum on the apex of the central anticlinal, which might have been fixed upon on the south outcrop, some four or five miles to the south. Notwithstanding the conviction entertained by me for many years, of the utility of the theory, I deemed it necessary to have extensive sections made by others, upon which to work it out before sending it forth to the public. This opportunity did not offer itself until after the publication of the Sections of the Geological Survey of Great Britain, and on applying it to one of them, known as the Caswell Bay and Penllergaer Section, extending from the former place through Penllergaer to the north outcrop of the coal measures, I found the results, by working from either side or basseting edges of the Coal Strata, north or south, according to the average angle of inclination of the beds, to be precisely the same at the outcrops as given in the Section; but with a material difference in the centre of the Basin, the curvilinear form giving a depth of some hundreds of feet more than the angular.

# TREATISE ON THE COAL FIELD

OF

# SOUTH WALES.

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"A knowledge of our subterranean wealth would be the means of furnishing greater opulence to the country than the acquisition of the mines of Mexico or Peru."—SIR J. SINCLAIR.

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THE substances which enter into the composition constituting the crust of the earth are Silica or Quartz, Alumina, Felspar, Lime, Magnesia, Potassa, Soda, Mica, and Hornblende, with several others of rarer occurrence; to which are added the numerous metals, with Carbon and Sulphur. It is computed by some that nineteen-twentieths of the entire composition of the earth is made up of Oxides, Silica, Alumina, Iron, Lime, and Magnesia, more or less impregnated with Carbon and Sulphur. The rocks which they constitute are divided into stratified and unstratified. The Unstratified Rocks are supposed to have been formed by intense heat in the interior, and thrown up in masses of a crystalline nature, and are termed igneous or Plutonic rocks. The Stratified Rocks are held to consist of the fragments of Plutonic rocks, and to have be endeposited from a temporary suspension in water; and hence the

term "sedimentary" is used to characterise the strata forming this class.

The Unstratified Rocks are:—

| | |
|---|---|
| Granite<br>Greenstone<br>Porphyry<br>Lava | More or less crystalline. |

The Stratified or Sedimentary Rocks are:—

| | |
|---|---|
| Gneiss<br>Mica slate<br>Clay slate<br>Chlorite slate<br>Quartz rock<br>* Primary marble | Primary Series. |
| Graywacke<br>Transition limestone<br>Old red sandstone<br>Mountain or carboniferous limestone<br>Carboniferous sandstone or coal strata proper<br>Magnesian limestone<br>New red sandstone<br>Lias limestone<br>Oolite<br>Greensand<br>Chalk | Secondary Series, containing the remains of animals and plants for the most part of extinct species. |
| London Clay<br>Paris strata, &c. | Tertiary or Upper Series, containing the remains of marine animals, quadrupeds, and birds. |

* These strata are rarely, if ever, found to follow each other in regular order as they are here classified, many of them being absent or intercepted—as, for instance, the Old Red Sandstone is intercepted by the Graywacke in Pembrokeshire.

The Granite appears to occupy the lowest position in the crust of the earth, and presents the appearance of a crystalline aggregate; its most characteristic components being quartz, mica, and felspar, which enter into its composition in various proportions, indiscriminately blended together, and thus evidently exhibiting the appearance of a simultaneous formation. Gneiss is distinguished from granite by having a laminar and not a crystalline form, but its constituents are much the same. Mica slate, which is the next in the series to gneiss, is, in some cases, closely associated with granite; indeed, in some instances, it comes in contact with it. This does not seem to retain any definite, uniform, chemical character, and is frequently found to graduate, by imperceptible degrees, into the rocks usually above and under, so as, in some cases, to make it difficult for the most acute to distinguish the transition. It has no particular metalliferous character, but it is important to observe that mica slate is probably richest in minerals near its junction with the granite. Clay slate is an important stratum, from the quantity of minerals it contains in some countries. Chlorite slate is composed of quartz and foliated chlorite. Quartz, though usually classified with the stratified rocks, does not appear to possess their structure, but we presume that owing to its continual occurrence in some of those beds, it has been associated with them. Primary limestone is usually considered a simple rock, consisting for the most part of carbonate of lime.

The next series of rocks, in ascending order, is the Secondary, to which belong the carboniferous sandstone, or coal and mine strata, to which we shall have for the most part to confine our attention, and this is again followed by the Tertiary or Upper Formation.

## THE COAL FIELD.

The Coal Field of South Wales extends from Pontypool on the east, passing by Risca south of Caerphilly, through Pentyrch on the Taff, Llanharry, north of Bridgend and Pyle, passing under the waters of Swansea Bay by Taibach, near Aberavon, appearing again between Swansea and the Mumbles, and crossing the Peninsula of Gower, and Carmarthen Bay, in its course for St. Bride's Bay. It trends to the north again through the Gwendraeth Valley, by Llandebie, Hirwain, Merthyr, Bute, Sirhowy, Nantyglo, and on to Pontypool. It is estimated to occupy an area of upwards of 700,000 acres, with a thickness of coal amounting to 95 feet, and ironstone workable by level operations about eight feet. One cubic yard of coal is generally considered to weigh about a ton, and a cubic yard of ironstone when stacked about 35 cwt. A solid block of that measurement would, in some instances, be nearly double that weight. It is regulated in its density by the per centage of iron it contains, that being heavier than the other substances which enter into its composition.

The coals of this Coal Field are of three distinct qualities:—bituminous or caking, free-burning, and anthracite or stone coal. Bituminous or caking coal is that which is found impregnated with sufficient oily matter to cause the small, on burning, to adhere together and form coke. Free-burning will not bind, and contains merely the necessary quantity of volatile matter to burn freely. Anthracite or stone coal is that which burns without either flame or smoke, and in some instances contains a small quantity of bitumen. Its specific gravity is somewhat greater than that of the other coals, averaging about 170.

There is also a peculiar kind of shale in this Coal Field; it resembles in appearance very opaque coal, and is supposed by some to be a near approximation to pure carbon.

The ironstone interstratified with the coal measures is of two different kinds, argillaceous or clay, and carboniferous or blackband. Carbonic acid, alumina, and silica appear to be the prevailing substances which enter into the composition of the former; carbonic acid, alumina, silica, and bitumen, the latter. Blackband resembles in appearance the dark shale beds of the coal measures, so that it is frequently very difficult, without exposing it to the action of fire, to distinguish the difference, especially when the shale is impregnated with sulphur, as is often the case. A method which may be adopted in cases where other means are not available, and which we should recommend to explorers, is to cut the suspected shale with a knife; if it prove gritty under the operation, and interlined with grey streaks, the probability is that it contains little or no iron; if, on the contrary, it cuts dark, with a dim lustre, the chances are in favor of its being more or less mixed with iron. The per centage of iron in the argillaceous ironstone* varies

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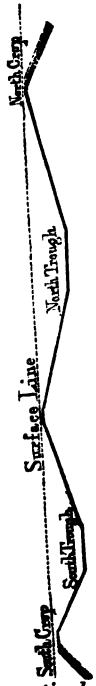
* Analysis of the ironstone of the South Welsh Coal Field, by Dufresnoy and Berthier.

| | USUAL ORE. | | RICH ORE. |
|---|---|---|---|
| Protoxide of iron ..... | 41.4 | .. | 54.1 |
| Lime ..... | 6.0 | .. | 0.0 |
| Insoluble residue ..... | 22.8 | .. | 8.0 |
| Carbonic acid..... | 29.8 | .. | 37.5 |
| | 100.0 | | 100.0 |
| Yield of iron ..... | 31.4 | .. | 42.0 |
| Yield of the same calcined. | 44.7 | .. | 60.0 |

considerably in different parts of the Coal Field. It is richest on the south outcrop; but the average thoughout the Basin is about 33 per cent. There is also found, in connection with the limestone, &c., an iron ore termed Hematite, which appears to be, in some districts, very abundant and rich in iron. It is met with in loads, and, in one or two instances, interstratified with the accompanying beds. At Pentyrch, in the Taff valley, this ore is worked, and is there to be seen presenting a stratified appearance in the carboniferous limestone.

[Diagram No. 1.]




Geologists represent this immense treasury of mineral wealth to be divided into two elongated curvilinear troughs, their major axis being east and west, with a ridge between, known as the anticlinal or Mr. Conybeare's axis of elevation—better known to miners as the "saddle-back;" Welsh miners term it *Cefn y cyfrwy*—with two synclinals or troughs, one north and one south of it. With all due deference to their opinions, our convictions are otherwise; and we have invariably found it more approximating an angular form, such as Diagram No. 1 represents.

We shall, however, leave this part of the subject for the present, and proceed with a classification of the various strata composing this immense basin of minerals, in such a manner as we trust will be of service to the *practical* miner, and also, in its progress, prove the truth of our theory.

### OLD RED SANDSTONE.

The Old Red Sandstone is usually deemed the base of this grand superstructure of mineral wealth, and the gray-wacke, the next stratum in descending order, (save where the transition limestone appears,) which is the lowest stratification in the Secondary Series, is occasionally found passing, by imperceptible degrees, into this rock. It varies very much in appearance and quality, and is sometimes a compact sandstone; at other times it is found a dark, reddish grey conglomerate, composed of quartz and other fragments of various sizes, imbedded in sandstone, made up in a great measure of comminuted mica and felspar. It contains the remains of fishes, and other fossils.

### CARBONIFEROUS OR MOUNTAIN LIMESTONE.

The next stratum we arrive at, in ascending order, in the mass, is the Carboniferous or Mountain Limestone. This is the stone made use of as a flux in smelting iron ore; and one ton of it is supposed to be required to produce one of pig iron. That part of it containing the least proportion of calcareous spar interspersed through it in veins, I have invariably found to be by far the best for this purpose. It is of a compact structure, varying from a blueish-black to a light grey colour, and remains of marine animals, &c., are lavishly embedded in it.

### MILLSTONE GRIT, OR PLUM-PUDDING STONE.

Superimposed on the mountain limestone is the Mill-

stone Grit, or Plum-Pudding Stone. It is composed of quartz, pebbles, &c., of various colours, the lower part of which is agglutinated together by a calcareo-argillaceous deposit, but higher in the mass, in some localities, it loses a portion of its calcareous composition, which is apparently replaced by an equal quantity of silex, and when such is the case, it is very much used for the hearths of blast furnaces, &c. It is, in some cases, overlaid by a black shale of considerable thickness, some of which resembles, in appearance, the black-band ironstone, and contains a small proportion of iron, being, as I believe, identical with the Gower shales, found reposing on the carboniferous limestone in that peninsula.

### THE FAREWELL ROCK.

The next stratum we arrive at upwards in the series, is the Farewell Rock, on which is reposed the whole of the coal and ironstone measures. This is composed of fragments of quartz, indiscriminately blended together by a silicious cement, &c., and in some instances very much resembles disintegrated granite, and also the upper portion of the millstone grit, becoming one with that conglomerate, in the absence of the black shale, which is occasionally found to intervene. This rock, from its " tough properties" in resisting heat, is found to be superior to every other stone met with in this country, and is consequently preferred for that purpose, whenever obtainable. Immediately over the Farewell, and separated from it by only a small vein of coal, and a few feet of shale, &c., is another fire-proof rock of considerable thickness. It is a hard sandstone, and the same as was made use of by our

ancestors of the 16th and 17th centuries, to *case* the inside of their smelting furnaces, the ruined remains of a few of which are still to be met with, here and there, on the southern edge of the Basin. This is sometimes called the Farewell. The position and lithological character of the Farewell has not as yet been properly defined; there appears to be some diversity of opinion respecting it. The millstone grit in some localities is known as the Farewell, in others the rock denominated here; while in many districts, the hard mass of sandstone just mentioned goes by that name. The different views existing with regard to the true position and nature of this rock arise chiefly, I believe, from the apparent absence, in various places, of the rock here distinguished as the Farewell, when either the millstone Grit or the mass of sandstone just named is substituted for it, and becomes the established Farewell Rock of those localities; and it occasionally happens, that a geologist in examining some districts, will not find more than *one* of those rocks exposed to view; whereas, the miner, on the contrary, will, in driving across the measures, meet with the *three*.

Above the sandstone, overlying the rock here denominated the Farewell, are the numberless beds of ironstone, coal, &c., which constitute the workable measures of the South Welsh Coal Field, and it is to the convenient and advantageous arrangement of these deposits, in this, as well as other fields in this country, that England is, in a great measure, indebted for the proud position she holds amongst the nations of the earth, and which is the pride and boast of every Briton.

## THE COAL MEASURES.

In my description of the Coal Measures, I shall divide them into three separate parts:—The lower line, or white-ash measures, which are accompanied by the "rakes" of ironstone; from these, the iron establishments throughout the basin receive their chief supplies;—the Pennant, middle, black-band, or brown-ash;—the upper, red-ash, or Mynyddyslwyn measures.

## THE LOWER, OR IRONSTONE MEASURES.

The Lower, or Ironstone measures, are separated from the Pennant or black-band by the *Cockshot** Rock. It is a quartzoze, with green and grey-coloured pebbles, which are united together by a fine siliceous cement—the grey tint appearing in most cases to prevail. When this stone is found to have been exposed to the atmosphere for any length of time, it then presents an appearance approaching cream-colour, and is easily distinguished from the sur-

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* This word "Cockshot" was first used in this country to distinguish the boulders which are distributed over the surface covering the coal measures, to which the stratum of rock now known as the Cockshot, has a striking resemblance. When the Black Cock of the mountain, or *Ceiliog du y Mynydd*, was common in this country, it was frequently found perched on these boulders, from whence it was shot by the natives with their long-range guns; hence the terms "Cockshot Rock," or "*Carreg Saeth y Ceiliog*." This bird, a large and noble species of grouse, was sometimes denominated by the natives *Ceiliog y Garreg*, or "Cock of the Rock." In Monmouthshire, these boulders, and the cockshot stratum of rock, are known to the miners as the *gwenithfaen*, or wheat-grained stone or rock.

rounding rocks. Some little distance below this, and therefore within the prescribed limits of the lower or line measures, are the well-known beds of ironstone, the soap veins, and black pins. A knowledge of the nature and appearance of these ironstones and the Cockshot Rock, under the slight differences in which they exhibit themselves in various localities, is almost indispensable to an explorer of the Basin, and we know of no other strata so well calculated to give him an idea of his position generally—one demonstrating the other; and, however much the coal seams, &c., may vary in quality and appearance (for instance, from bituminous to anthracite), we scarcely ever find any great difference in the cockshot and black pins.

The next stratum of any importance we arrive at, in descending order, in the lower or line series, is the Ellid rider of coal, overlying a close-grained sandstone of the same name, beneath which lie some balls and nodules of rich ironstone, with a very important vein of coal, known in most places on the south crop as the "new vein." On the north crop its name differs very much, but the Ellid sandstone, which is immediately over it, retains that name throughout the north and eastern edge of the Basin. It has a white ash, and emits intense heat, being generally considered a superior coal for steam purposes, and for smelting iron. This is again followed (in descending order) by a succession of beds of coal and ironstone, the lowest portion of which is very abundant, and rich in ironstone, on the south and south-east outcrops of the Basin. In the district between the River Taff on the east and Swansea Bay on the west, there has been found, by actual workings in three places (some distance apart), a thick-

ness of upwards of 100 inches of ironstone in 100 yards breadth of ground, yielding, on an average, something more than 35 per cent. of iron. There is to be observed in these lower rakes of ironstone, a *Pin*, which is designated by the miners *Tobacco Pin*, from its resemblance to a roll of twist tobacco. This, from its uniform and unalterable appearance throughout the Coal Field, claims the particular attention of the geologist and surveyor, as its consistent position in the measures renders it of the utmost importance in classifying the ironstone beds of one district with those of another: indeed, we have found this peculiar bed of ironstone, in many instances. of considerable assistance, particularly in maiden districts. In the Merthyr district, and around the north and east outcrop, it accompanies the rough pin, &c., between the second and third vein of coal, in ascending order, in the coal strata. On the south outcrop of the Coal Field, from the Rudry works on the east, and Carmarthen bay on the west, it is met with between two seams of coal, identical in position to those it intervenes on the north crop, and known through a considerable tract as the two *Cribwrs*. We also find in this series, nodules of ironstone, comprising compartments with the impressions of plants, and sometimes leaves, forming a nucleus, as it were, around which argillaceous matter and carbonate of iron have been collected, forming in many instances, balls of ironstone, from six to eighteen inches in diameter. These on the south outcrop are much superior in quality to the accompanying bands, often containing as much as 40 per cent. of iron. When they range in regular bands with the stratification, and not indiscriminately, as is frequently the case, geologists denominate them septaria, and occasionally geodes; the first signifying partitions, and the

latter, an earthy substance hollow in the centre. The terms most commonly used by the Welsh miners, are werricks, small nodules, balls or large nodules. Perhaps the most interesting nodule of ironstone to be met with in this series, is that which presents, when broken, an oval-shaped cavity, of from two to three inches in diameter. In the invert dome of this, we have repeatedly observed a crystal of wonderful brilliancy, many of which were little inferior in lustre to a sudrass, a Sulbampoor diamond of the fourth class. It is a rather remarkable coincidence, that diamonds of the first water are occasionally found imbedded in iron ores in South America, occupying a drusy cavity in much the same manner as the crystal met with in the ironstone nodule just mentioned.

Fossils are sparingly found in the beds of this series, which averages an entire thickness of about 2000 feet, on the south rise of the south trough, from the Cockshot Rock down through the lower workable rakes of ironstone in the district intervening the River Taff and Swansea Bay. In going eastward from the River Taff, there appears a considerable decrease in the thickness of this series; and on reaching the vicinity of Pontypool it does not exceed 500 feet, the cause of which will be hereafter adverted to.

There is some difficulty in defining the exact point of termination of the lower rakes of ironstone to the west of Swansea, as considered to the east of Swansea Bay; arising chiefly from an indiscriminate blending of the constituent ingredients of the formations usually reposing on the mountain limestone; but if we take the thickness of the whole series, from the Cockshot Rock down to the carboniferous limestone in the Ogmore district, and compare it

with the same below or west of Swansea, the difference is scarcely perceptible. We cannot, therefore, consistently consider the lower or ironstone measures to increase, from the longitudinal centre of the Basin in a westerly direction, but merely that the millstone grit and the shale of the Ogmore district, has been substituted in that direction by a shaly conglomerate, though presenting an obvious difference in a superficial point of view, yet containing, but not in the same order of combination, all the amalgamated matter forming the millstone grit, and its accompanying beds, constituting sandstone, quartz, ironstone, and calcareous matter. This is, perhaps, the more manifest from the fact, that on the north outcrop, opposite the Swansea district, the millstone grit appears, and is there found with the shale, in precisely the same order of superposition as on the south outcrop in the Ogmore district to the east.

The thickness of this series is considerably less on the north, than on the south outcrop; the diminution being in the same proportion as the decrease in the angle of dip, in compliance with a theory which will be explained in the following pages.

It is the prevailing belief of those engaged on the north outcrop of the Basin, that a ton of iron cannot be manufactured at the same cost on the south. This does not appear to be the case, and arises chiefly, we believe, from the notion entertained by those accustomed to workings on the north rise, where the angle of inclination in the strata is seldom more than 10°, that to prosecute operations on the south rise, where the angle of dip is rarely under 35°, and frequently more than 40°, must be neces-

sarily attended with greater expense. Certainly the coal is stronger and more compact on the north rise, but this is again counteracted by the superior richness of the ironstone on the south, which gives a greater per centage of iron, and is, in most cases, found more profusely distributed, so that, on the whole, the cost of producing a ton of iron is pretty well balanced on the north and south side of the Basin*. That which appears to be the disadvantage attending Iron Establishments on the south edge of the Basin, is the want of forges to convert the pig into bar,—as bar iron invariably commands a better price than pig in the markets, compared to the cost of production.

Before proceeding with the next series, we would here observe, that particular attention should be paid to the construction of furnaces on the south rise; as one of a form answering the most sanguine expectations on the north outcrop, would in most instances be a comparative failure on the south. It would be advisable, therefore, prior to the prosecution of a new establishment, to test the quality of the materials to be used, in order to arrive at a proximate knowledge of their smelting scale; and to erect the furnaces accordingly.

This may be deemed of little moment by some; but we augur the time to be not far distant, when this principle will be found of the utmost importance; and the necessity

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* Average thickness of ironstone between the second and third vein of coal, in ascending order, in the coal measures from Aberdare to Nantyglo, on the north crop, 67 inches. Average thickness of the same from the Ebbw River to Carmarthen Bay on the south rise, 84 inches.

of strictly attending to it will become the more obvious as the increase in the manufacture of this useful metal proceeds. In making experiments on the coal and ironstone of several districts on the south rise, some few years back, the smelting scale was found to vary considerably, in localities not far distant from each other; and what appeared very remarkable, in many instances the fusing properties of the ironstone increased and decreased, in the same proportion as the increase and decrease in the strength of the coal.

We would also remark, that the anxiety felt in many cases, for introducing the blast into furnaces, immediately after their completion, and before the materials of which they have been constructed have been perfectly nealed, is more injurious than we are generally disposed to give credit for. The gases generated by the damp materials when the blast is put on, have a tendency to produce large fractures in the buildings, through which a considerable quantity of heat escapes, thus rendering, in a great degree, a large proportion of the action of the blast latent, which would have otherwise acted on the charges in the furnace. This very frequently causes great irregularity in their working stability, when recourse is had to the burden, which is altered to bring the furnaces back into proper working order. This is invariably attended with considerable inconvenience and expense, as the waste of iron arising therefrom, and passing off in combination with the cinders or dross, is very great; indeed, those only who have kept an account of the number of waste charges which ensue in a few weeks in furnaces tolerably compact in structure, can form the slightest notion of the extent of loss effected through the inimical tendencies

of those apertures in cases where they are considerable; even in one furnace, the amount of waste arising therefrom is scarcely credible; then what must it be in an extensive iron establishment, such as that of Sir J. J. Guest's, where there are nineteen! We should, therefore, recommend that four spiral flues be carried up with the building, each flue to terminate at the top perpendicularly over the point where it commences at the bottom, and communicating with air stoves on the hearth, in which fire should be unceasingly kept as the structure progresses, so that, on completion, it would be in a fit condition to admit the blast, and thereby effectually avoid the fractures which would otherwise ensue.

### THE PENNANT MEASURES.

The next series of measures we arrive at upwards in the mass, with the Cockshot Rock, as its base, is the middle, Pennant, or Blackband. This is separated from the upper Mynyddyslwyn, or red-ash measures, by the upper tilestone rock, containing silex with a good deal of mica, splitting in thin laminæ of from half an inch to an inch in thickness. This series averages a thickness, on the south rise of the strata, between the River Taff and Llanelly, of about 2,800 feet. Some of its beds of coal are in high repute for steam purposes, and the fire-clay of this division is superior in quality to any other found in the Basin. These beds are frequently accompanied by Blackband of a superior quality, and in the Llynvi district there are three seams of it, averaging, in the aggregate, a thickness of about four feet six inches. We do not find this carboniferous ironstone accompanying the same beds of coal throughout the Coal Field. That which we find in

one district as blackband, is very often a carboniferous shale in the next, and *vice versa*. We are indebted for the discovery of this valuable deposit containing iron, to the late Mr. Mushett, of the Forest of Dean. Mr. Hampton, of Maesteg, was the first who made use of it in that rich mineral district just alluded to. On the brow of the hill just above Cwmdu Isha farm-house, on the east side of Cwmdu, near Maesteg, there is a heap of iron cinders with the slight remains of a smelting furnace. Near this spot there is an old level, working on the vein of coal immediately over the upper seam of Blackband. By the site of the old furnace, we found some of that carboniferous ironstone in a partially calcined state. When we consider that this ironstone requires but little flux in smelting, and remembering the distance of this place from the nearest limestone, it leads us to infer that the Blackband was well known to the ancients. The following is an assay by Mr. Mushett, of the lower Blackband, in the Pennant series at Maesteg:

| | |
|---|---|
| Carboniferous ironstone, free from sulphur, but mixed with a layer of schist, lost in roasting .. | 36.81 |
| Yielded from the roasted stone of excellent grey iron | 57.13 |
| Yielded from the raw stone ..... | 36.2 |

The same by Messrs. Johnson and Cook, of London:—

| | |
|---|---|
| Peroxide of iron ..... | 63.5 |
| Moisture ..... | 2.5 |
| Water of composition carbon and carbonic acid .... | 32.0 |
| Trace of manganese, loss..... | 0.7 |
| Alumina..... | 1.3 |
| | 100.0 |

There is a peculiar kind of conglomerate accompanying the Pennant rocks, which is not to be met with in other measures; it is composed of quartz and nodules of ironstone, cemented together by arenose argillaceous matter, and the water oozing out at its crops seems strongly impregnated with *carbonate* of *iron;* which, since the discovery of black-band, has led to some fruitless speculations, from the resemblance of *its crop* waters to what is found about the basseting edges of that ironstone. There is also another conglomerate in and about the faults* of this series, somewhat resembling the above, with the exception of the absence of the nodules of ironstone, and is identical with the boulders we so often meet with in spots covering the crops of these measures. We need only ask the husbandman who has been instrumental in cultivating some portions of those rustic areas of brushwood, fern, and heather, to learn the immense extent of the distribution of these boulders. Some deem them to be the debris of the old red sandstone, and to have been mechanically transported to their present destination by water, probably during the "Great Flood" which inundated the earth; but a strict examination of them will, we think, suffice to convince us that they are made up of the constituents of the surrounding sandstones, separated and broken up into minute fragments at the time of the great convulsion in nature which produced the anticlinal lines, and forming the matrix for particles of quartz of various sizes—a crystal which is found profusely imbedded in the lowest rock of this series. The coal of the Pennant measures is not usually considered so power-

* A "fault" is a dislocation of the strata.

ful for smelting iron as that of the lower or line—notwithstanding the lowest beds produce pig iron of an excellent quality. The best pig iron we have ever seen was smelted with two-thirds of the lower beds of Pennant coal and one-third of the line; but the chances are, as we proceed upwards in the mass, that its merits become impaired by sulphur, which is found inimical to the production of good iron.

The beds which are deemed the most favorable for making iron of this series, are the upper or big vein, but this only in some localities, and two of the lower; one of which has a strong rock roof, and is generally known on the south edge of the Basin as the rock vein. Openings on this may be seen, here and there, on the south side of Margam and Baydan mountains, between the Ogmore River and Swansea Bay, and also to the eastward in the Taff and Ebbw districts. This coal overlies a very superior bed of fire clay, from which bricks are manufactured equal to the best Stourbridge. On one occasion we tested the merits of bricks made of this fire clay, with those of Stourbridge and Dinas in the Vale of Neath. After submitting them to an intense heat for four-and-twenty hours in an air furnace constructed for that purpose, we found their capacities of resisting the action of fire about equal, the Dinas brick appearing less molten than the others, but considerably fractured, so that on the whole there appeared no material difference in their qualities.

At another period we submitted the Cockshot and Farewell Rocks to the same test, both of which seemed, on being taken out, considerably fractured and somewhat glazed; nevertheless, presenting a superior surface, such

however as is usually admitted to be capable of resisting the action of a very intense heat; consequently, in localities where the Farewell Rock cannot be conveniently obtained, we should recommend the substitution of the Cockshot for hearths of furnaces, which may be used with nearly equal benefit.

The upper, or as it is sometimes called, the big vein, varies considerably in thickness, and is met with from one to nine feet thick. It is, in some instances, thinnest on the south rise; it occasionally separates and becomes two, and sometimes three, with a considerable extent of stratification intervening. This is a common occurrence with a few of the beds of coal in the Basin, but it is generally confined to localities, so that we have no reason to expect that a bed of coal of nine feet in thickness in one district, should be the same in the next, as it may have been divided into two or three, or as it is technically termed, the mother bed may have thrown out wings; but as we have previously observed with regard to the lower or ironstone measures, there is little difference found in the thickness of an entire series, until we approach the eastern or western extremity of the Coal Field.

At some little distance beneath the big vein, there are to be met with, in some districts, pins and nodules of ironstone: though generally of an inferior order, they are nevertheless occasionally found of good quality, and it sometimes happens that in following up the best specimens for a short distance from the outcrops, to find them completely metamorphosed into the Rocks with which they are associated. To account for this change, though very common in the ironstone of this Coal Field, would be rather

difficult, unless it may be considered to have arisen from water* holding a sulphate of iron in solution, which was precipitated in its passage over the crops of those strata, and which gradually produced, by electro-chemical influence, the transmutation.

The same principle appears to have been carried out in converting the shale into blackband ironstone; consequently, what we find a bed of carboniferous shale in one district, and blackband in the next, proceeds from the same law. It would not be incompatible, therefore, to assume that this valuable deposit exists to a much greater extent in the South Welsh Coal Field than is at present known, but from what has been previously observed, it appears very irregularly disposed, and a dislocation of the strata frequently cuts it off entirely. Thus it often happens that a bed on one side of a fault gives a good per centage of iron, whereas, on the other it is worthless, and what is perhaps very extraordinary, in pursuing this same bed across a second dislocation, the chances are that the iron is restored.†

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* Water is a compound body composed of hydrogen and oxygen. One hundred parts of water is reckoned to consist of 88.9 of oxygen and 11.1 of hydrogen. Water is never found pure in nature; it invariably holds foreign matter in solution. That of the South Welsh Coal Field is strongly impregnated with salts of iron, (in some instances, sulphur,) and the red oxide so common about the crops, &c., of the coal measures, results from an absorption of oxygen from the atmosphere, the carbonic acid by which it was held in solution being evolved at the same time.

† When loads or veins intersect beds in stratified districts, it is generally considered that the difference of level produced by a disloca-

Fossils are rather abundantly dispersed through this series, indeed so plentifully are they found in the shales, &c., covering the upper seam of coal just beneath the upper tilestone, that it would be hardly possible to pick up a single piece, however small, without slight traces of impressions. We see the rocks of the Pennant series, here and there, exposed to view along the escarpments of those high hills on the southern edge of the Basin; and the cock-shot rock, which is their base, is to be seen at intervals basseting out along the sides and sometimes at the foot of those escarpments, passing under Swansea Bay, by Tai-bach, near Aberavon, in its course to the western extremity of the Basin.

The Pennant stone raises generally in well-defined beds from three inches to three feet or more in thickness, and weighs from 165 to 170 lbs. per cubic foot. This makes it particularly convenient for every description of building purposes. It is, we believe, from the advantageous nature of this stone for all kinds of mason work, particu-

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tion of the strata influences materially their productiveness. When three beds overlie each other, viz., limestone, sandstone, and shale, the two former productive, and the latter unproductive, a dislocation which has thrown the shale opposite or on a level with one of the productive beds, is invariably accompanied by unproductive results. Coupling this with the fully-established fact of electricity having the power to select, and the momentum to convey, elements or finer particles of matter, through other matter more open and porous, we are led to the conclusion, that the distinction to be observed in the quality of the same bed of ironstone and blackband arises out of the same law. If such be the case, it would be quite consistent for the same beds of blackband to present considerable disparity in their per centage of iron in faulty districts.

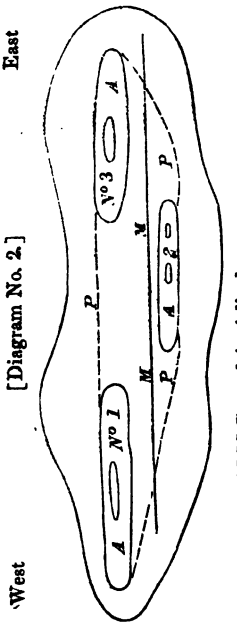
larly walling, that masons accustomed to the use of it are invariably found to be superior artisans.

### THE RED ASH MEASURES.

The next series of measures in ascending order, with the upper tilestone as a base, is the upper Mynyddyslwyn or red-ash. It is the coal of this series which has been so extensively exported from Newport for the last 50 years. It cannot be used for smelting iron, the great quantity of sulphur it contains rendering it unfit for that purpose. It is rather remarkable that this coal will produce more gas and tar than that of the other divisions, and faults are met with in greater abundance in the beds of this series, than in those they overlie. The cause of the latter may be attributed probably to their superior position in the measures, making them thereby insufficient to sustain the upward pressure, which was put in action to form the anticlinal axis, with the same degree of regularity as the under beds. A general fact, of rather a singular nature, connected with one of its best beds of coal, may be here related. This bed is separated into two, sometimes by a rock, and sometimes by a "clift." When a clift, the coal is soft, the roof is weak, and the bottom "pucks" exceedingly: but when a rock, the roof is good, the coal is solid, the bottom hard, and if struck with a pick, sounds like a bell.

The rocks of the red-ash series differ somewhat from the Pennant, and instead of raising in well-defined layers, are frequently irregular; sometimes a compact sandstone of considerable thickness, and at other times splitting into

false beds, which are at every six or seven feet, occasionally less, intercepted by vertical and slightly oblique joints, which preserve a very uniform degree of parallelism. This, from its being the highest division of the coal measures, and consequently of narrow limits in a transverse direction, appears to have been governed in its position by the direction taken by the central anticlinal throughout the Coal Field, which flanked it north and south according to local circumstances, edging it south at the eastern and western ends of the Basin, turning it over into the south trough in the centre, and flanking it on the north.




[Diagram No. 2.]

M M M Central Anticlinal.
P P P Original position of the Upper Series.

This series varies considerably in thickness in different parts of the Coal Field, and is found from three thousand to one hundred feet thick. On the south rise near Swansea, it is about three thousand feet. No. 1 A. In the south trough its greatest thickness is under four hundred feet, and frequently there is not ground to admit any of its beds to take up a position. No. 2 A. In the north trough, Monmouthshire, it does not appear to exceed seven hundred feet. No. 3 A.

Fossils of nearly every variety known to exist in coal formations, are found to be more or less distributed in the beds of this series. The most common being the lepido-

dendron, calamites, sigillaria, ferns, and the stigmaria ficoides.

The most perfect specimen of a fossil tree the author has ever seen, was discovered by his father, the late Mr. Moses Moses, mining and civil engineer. It was met with in the under plane of a bed of shale, reposing on a seam of coal. Though great precaution was observed in its removal, it nevertheless received considerable injury, but it was afterwards refitted, and a drawing made of it. There appeared a difficulty in identifying its species, but it seemed to have a stronger resemblance to a young poplar than any other known tree or plant, fossilized or otherwise. The lepidodendron is met with in great abundance in some localities, but we never saw them in such profusion as in an open cutting on the South Wales Railway, near the town of Neath, one of which (the lepidodendron Sternbergii) when measured with a tape line, was found to reach the enormous length of one hundred feet. This is, we believe, the largest that has ever been discovered in this country, or probably in any other, and those who may wish to see this gigantic specimen, may be gratified with a view of about thirty feet of it, imbedded in a rock on the north side of a railway cutting to the back of Courtherbert, at a distance of about one hundred yards from the entrance, and within one mile of the town of Neath. The interior of this fossil is a hard compact sandstone, somewhat finer in its granulation than the rock in which it is imbedded, and the bark or cuticle slightly tinged with a dark glistening bituminous matter. The calamites and sigillaria are also very prevalent, some of which have come under our notice in a state of good preservation. Ferns are likewise very numerous in some localities; we have repeatedly ob-

served the most perfect specimens to be more manifestly abundant in the shale approximating the big vein—the highest bed in the Pennant series. They are apparently of much more luxuriant growth than those at present existing in this country. In the softer portion of the beds in which the fossil fern is found, particularly in what the Welsh miners term *pouncing*, we have frequently noticed small elongated nodules of ironstone, which are known to the miners as werricks, and which we have often observed to have a striking resemblance to the roots of existing plants.

On the return of our friend Captain Davy, of Sarnfawr, from New Zealand, where he had been staying for about three years, he shewed us the roots of ferns which flourish luxuriantly on that island, and which the natives there substitute for bread. The manifest similitude between these roots and the werricks in connection with the fossil fern, has led us to suspect that those nodules or werricks of ironstone are probably the roots of the fern, fossilized.

The stigmaria ficoides is considered by some to be the most prevalent fossil in the South Welsh Coal Field, but, unlike the others, is supposed to be entirely confined to the fireclay. Our observations, however, of this fossilized plant, lead us to directly opposite conclusions, as we have occasionally seen traces of it in the accompanying beds.

The circumstance of Mr. Logan, of Swansea, finding these plants in inconceivable quantities in the fireclay, which forms, as he states without exception, the substratum

of coal beds, has given rise to a theory on the formation of coal, which is now considered, by some of our principal geologists, to be the most compatible hitherto propounded on the subject. It is, we believe, somewhat approximating the following:—The stigmaria ficoides is supposed to have been a floating plant, of a dome-shaped body, with branches arising out of the periphery of its disc; these flourishing in inconceivable numbers in the bottoms of shallow lakes or lagoons, formed, after a series of the most prolific vegetation, beds for a still larger and more luxuriant growth of plants, more arborescent or tree-like than the former, which, on decay, mixed up with the detritus brought down by the rivers, &c., feeding those depositories; when, after a numerous succession or necessary complement of this prolific growth of vegetation, subsidence ensued, which was followed by ruin and chemical changes, and which, under compression, was entirely converted into a bed of coal. To account for the numerous beds of coal we find in coal fields, it is supposed, that after a time an elevation took place, and the uplifted area became the scene of another or second prolific growth of vegetation, which, in its turn, was submerged, and so on until the whole series was formed.

We must here remind the reader that there is no proof of the stigmaria ficoides being a floating plant, as such is only a supposition based on the appearance occasionally presented by this fossil in the fireclay; indeed, it may with equal probability be considered a horizontal plant, flourishing in great profusion in morasses like those edging or lining the Mississippi, and subject to periodical inundations which deposited great quantities of detrital matter, and analogous to a creeper, from which arose vertical and

larger plants, probably somewhat like the Ara Tree of Borneo, the hard cuticle at the base of which, from its being protected by the detritus resisted entire decomposition, whilst the upper portion, and even the core of the remaining part of the cuticle at the base, disappeared amongst the surrounding collection, so that the cylindrical-shaped cavity occasionally presented by this fossil, may have been the preserved part of the cuticle at the base of the larger plant arising out of the creeper.

It matters little to us, however, as far as regards the South Welsh Coal Field, whether the stigmaria ficoides were a floating plant or otherwise,—as that cannot aid us much in developing its productions; indeed, fossils are more immediately connected with the comparison of one geological zone or system of deposits with those of another; even then great precaution should be exercised in the use of them, as there is ample evidence in the Coal Field of South Wales to shew that the deeper we penetrate, the more scarce and illegible the fossils become;—or whether coal were formed out of rank vegetation which may have grown on the spot, or the remains of impenetrable Tropical forests, transported by the waters of rivers like the Mississippi and others, and deposited with an heterogeneous debris, in lagoons and estuaries of former continents, and, which on being subjected to the influence of the secret and irresistible powers of the anticlinal lever, became elevated, as being more conducive to the wants of civilized man, whilst the continental deserts which supplied the necessary materials, were at the same time submerged beneath the ocean wave.

## NEW RED SANDSTONE SERIES.

The beds of this series do not repose on the coal measures of this Coal Field. They occupy the low grounds to the south, between the south outcrop of the coal strata and the Bristol Channel, and form the substratum of the fertile plains of the Vale of Glamorgan. The composition of this series of deposits is said to be,—magnesian, calcareous, argillaceous, arenaceous, and saline. These combined in various proportions, form the different strata,—lias limestone, sandstone, dolomitic conglomerates, &c.

It is the lias limestone of the Vale of Glamorgan, which furnishes the celebrated lime for building purposes known as the Aberthaw; but as this stone is chiefly collected on the beach, it is more than probable that its superior qualities arise, in a great measure, from its continual subjection to the action of the tidal wave, which, on every flow, rolls it about and cleanses it of any extraneous matter with which it may be interstratified*.

There is also found in this district, a very superior building stone, occupying a position, geologically, intervening the basetting edges of the carboniferous limestone and the unconformable beds of the lias. It is generally known as the Sutton stone, from a quarry having been

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* We infer this from the fact, that the limestone collected on the beach at Aberthaw, and which has been subjected to the action of the tidal current, is superior in quality to the same quarried at that place.

opened into it at a place called Sutton, near the mouth of the River Ogmore. It was at one time extensively shipped to neighbouring ports, and, in some instances, exported to the continent. The component parts of this stone appear to be sandstone, quartz, carbonate of lime, with slight traces of galena to be observed occasionally. We must consider it, therefore, a conglomerate, and like many rocks of that character, changes its colour, which, as seen in the quarry, has a brownish cast, but on being exposed and subjected to the action of the atmosphere, becomes nearly white or bleached. It is capable of being dressed to any form, with nearly as much ease and freedom as the best Bath stone, and weighs from 130 to 137 pounds per cubic foot.

It is somewhat remarkable that architects of the present day should overlook this stone, which could be easily and cheaply obtained, and which, for elegance and durability, is equal if not superior to any other met with in the kingdom, evidences of which, are amply manifest in its imposing and unalterable appearance forming the white-chequered quoins and ornamental parts of several of the ecclesiastical and baronial structures of Glamorgan, built by Lalys, an eminent architect of the twelfth century. Indeed, those who have seen the picturesque remains of Neath Abbey, could have scarcely passed unobserved the marked appearance of this stone, in that time-worn structure. The striking contrast between the white quoins, &c., and the darker portions of the cisterscian ruin, imparts a beauty and elegance to the whole fabric, so as to form a scenic object in the surrounding landscape, rarely equalled and not surpassed in Great Britain.

There are, also, many patches of dolomitic conglomerates, or as it is sometimes termed, magnesian limestone, with shaly deposits, &c., distributed through the Vale of Glamorgan, containing manganese, galena, hematite, and in some cases calumina, or black-jack.

At Llanharry, near Cowbridge, this conglomerate reposes on the millstone grit, and overlaps the outcrops of some of the lower measures of coal and ironstone. There is one patch of it a considerable distance in the Coal Field to the north of that place, and overlies the crops of the black pins ironstone, and some of the accompanying coal beds, at Hendre Owen Llanharen. This patch, or perhaps we should say, the lower portions of it, is to all appearance rich in hematite iron ore, and, from what we have observed, there is a probability of its proving a source of considerable profit, on the completion of the South Wales Railway, which passes within a short distance of it. The direction taken by the South Wales Railway along the south edge of this emporium of mineral wealth, will afford ample facilities for working many districts, rich in ores, &c., which now remain dormant for the want of available communication. This, coupled with the convenience that will be rendered, by its tributary branches, to many parts of the South Welsh Coal Field, now inoperative and of comparatively little consideration, will not only enhance the value of landed property* in many dis-

* We are acquainted with landed property in the Mineral Basin of South Wales, which is at the present time considered to be worth upwards of £100,000, and which could have been purchased fifty years since for less than £1000.

tricts to a very considerable extent, but will also, and ere long, place South Wales second to no other part of Great Britain, and the South Wales Railway one of the most stable railway undertakings.

We have before stated that the Coal Field is divided into two elongated troughs by Mr. Conybeare's anticlinal line, the major axis of which runs east and west. This elevated line of division enters the Basin on the east near Moidart, crossing the Ebbw River, the Sirhowy, by Velin-fach, the Taff Valley at Newbridge, through Blaen Ogwr, Cwm Garw, Maesteg, Cwm Avon, on to Baglan, whence it passes under Swansea Bay, and runs out of the coal measures near Swansea. The coal strata within the range of this line of elevation have been thrown up into gable-shaped masses, and the cockshot rock and black-pins ironstone are here and there exposed to view along its apex; from whence they dip, north and south, to their respective troughs on either side (followed, of course, by the other measures), at an angle of from 10° to 20° throughout the greater part of the Coal Field to the eastward of Cwm Avon. They assume a flat position in the centre of those troughs, from whence they rise, towards the extreme outcrop, south, at an angle of about 45°, and towards the extreme outcrop, north, at an angle of about 10°. At Baglan the dip increases considerably, and the measures there rise to and fall from the apex of the anticlinal axis at an agle of about 40°.

This view of the lower or ironstone measures, rising to, and falling from, the apex of the central anticlinal at Baglan, was corroborated by Mr. Struve, of Swansea, in a paper read at the meeting of the British Association, held

at Swansea in August last, as will be perceived by the following copy of what he read on that occasion:—" The Pennant rock stands, on the north and south side of Cwm Avon, and that the lower measures must necessarily pass, under Margam mountain, and crop out towards the sea." In compliance with this theory, pits are now being sunk in the neighbourhood of Port Talbot. The next section to which Mr. Struve alluded, was the Caswell Bay, and the Great Mountain in Carmarthenshire, constructed by him and Mr. Logan, and published in the Geological Survey. " It will now be observed, that the uprise has completely removed the continuation of the southern portion of the Coal Field, which exists between Margam and Lantrissant, and the limestone only is to be seen contorted in the manner described in the Section. Proceeding still more westward through Gower, the limestone is found completely broken up, and the old red sandstone protrudes through from beneath, which is illustrated in Section No. 6, constructed by Mr. Logan."

" Section 4, also constructed by Mr. Logan, from Port Tennant to Castle Cerrig Cennen, is introduced for the purpose of illustrating, by an addition which he made to the Section, the probable partial removal of the coal measures under Swansea Bay. It would appear, therefore, that the great central uprise of our Coal Field, which served so usefully to bring up the lower coal beds, &c., in various portions of it, is merely a continuation of what has acted with so much more violence in Gower, and that this movement may perhaps be traced back to Pembrokeshire."

This verification is, perhaps, the more remarkable, from

the circumstance that Mr. Struve was not aware, prior to the appearance of the first edition of this Treatise, that the central anticlinal continued through Cwm Avon and Baglan, on to the western extremity of the Coal Field, and brought up the lower or ironstone measures at those places, and formed a saddle-back as at Maesteg: moreover, the Reports in the Memoirs of the Geological Survey, vol. i, which accompanied the Sections to which Mr. Struve alluded, and some of which he assisted in making, are adverse to these views. As it is therein stated, in allusion to the cockshot rock of Maesteg, that it is seen at other places, and is probably the same as the sandstone so named at Briton Ferry, on the south outcrop of the coal measures, whereas Briton Ferry, is on the south bassetting edge of the measures in the north trough, and the south crop of the cockshot is near Taibach, on the south outcrop of the coal strata in the south trough, some considerable distance to the south. The statement made in the Memoirs relative to the probable existence of coal under the waters of the Bristol Channel is still more conclusive, as, had Sir H. De la Beche been aware of the extent and direction of the anticlinals in connection with this Coal Field, we are far from thinking but so able and eminent a geologist would have at once seen there were no grounds for such a supposition, beyond that of the narrow strip of the south outcrop of the coal measures crossing Swansea Bay from the vicinity of Taibach for Cline, inside the Mumbles head, to which the statement alluded to has no reference whatever. Mr. Ramsey, in his paper of denudation relative to this Coal Field, also arrives at the conclusion that the waters of the Bristol Channel cover an out-lying portion of this field of coal. This hypothesis is in accordance with the view taken of the anticlinals by that talented geo-

legist, but to consider that an out-lying portion of the coal measures takes up a position under the waters of the Bristol Channel, with a knowledge of the extent and direction of the anticlinals in connection with this Coal Field, is to us quite untenable.

We make these observations, in order to shew the distinction between the two views, as those unacquainted with the subject would be disposed to consider, from the manner it was introduced or treated by Mr. Struve, at the meeting of the British Association at Swansea, that the Sections of the Geological Survey were constructed with a knowledge of the extent of the central anticlinal and the position of the measures, as explained in the first edition of this Treatise, whereas such was not the case, &c., &c.

### ELECTRICAL EQUILIBRIUM, ETC.

The direction taken by the anticlinals across the Bays of Swansea and Carmarthen, is such as materially to influence the action of the tidal currents in those estuaries, and it is to them may be attributed the gradual filling up of the mouths of the harbours within their range, as the debris brought into those inlets by the Neath, Tawe, Llochwr, and Towy Rivers, is bayed up by the anticlinal ridges, and forms sand-banks of considerable extent, some of which are perpetually shifting their positions. It has often occurred to us, while observing these sand-banks, that the materials of which they are constituted were under the influence of a law which had the power of separately

selecting and arranging the momentum of passing particles of one description or character of matter through or between those of another; in other words, the law of molecular motion in matter. Indeed, the peculiar movements of the particles of matter in these secondary workshops of reformation, have been a source of admiration to us through many a toilsome and hazardous hour. At one moment may be seen a transference effected out of one position into another, and producing a movement assimilating that of a body of matter passing through another in a state of rest, and in the next every molecule in motion like that of a hillock of ants in full operation, from whence a transmittance is occasionally made to an apparently definite position.

The cause which effects the agent producing these movements, involves a difficulty. Electricity, we know, has the virtue to select, and the momentum to convey, elements or particles of finer matter, through or into the interstices of other matter more open or porous; but there are circumstances connected with this which places electricity in a secondary point, as these movements rise and fall with the tide, that is, as the tide flows these movements pass to a higher level, and as it ebbs fall back again. This indicates that electricity is a circulating fluid, the initial or inherent property of matter pervading space, conceivable or inconceivable, involving an antagonistic power by which it is set in motion, as the selecting and arranging agent. This antagonistic power appears to be friction, and emanates from the oscillating action of the tidal wave, from which it is apparently transferred, on much the same principle as that of a forcing pump, to the electric fluid, by which the electrical equilibrium is con-

stantly disturbed, and the electricity rendered perpetually active in its operations. The ebbing and flowing *well* of fresh water at Newton Nottage near Porthcawl, is another instance of this law. As the tide flows this well ebbs, and as the tide ebbs this well flows. This alternate ebb and flow of the fresh water in the well, evidently indicates that it is actuated by the pressure of the tidal wave operating on some intermediate fluid, which, in its turn, forces the water out of the well, and which, as the tide ebbs, relapses into its former condition, and permits the water to fall or flow back again.

There have been many hypotheses advanced by philosophers, relative to the way in which electrical currents are set in motion on the stratification or materials composing the crust of the earth, or the perturbation of electrical equilibrium by which electricity is rendered a repletive* agent, but, as yet, the conclusions arrived at are considered unsatisfactory. Some are of opinion that it results from chemical action taking place in the centre of the earth; others that it is generated by solar influence; and a few contend that it proceeds from the rotation of the earth on its axis. Our observations lead us to the inference that it results or is induced by the tidal wave, and that electricity is a property of matter, which requires an antagonistic power to keep it in a state of perpetual excitement, or by

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* Electricity is assumed to pass freely through the materials constituting the crust of the earth; and as metallic substances are more or less disseminated in rocks, the electric current, in its passage, selects and transmits these metallic substances into fissures, splits, cutters, &c. This is what is termed the repletion and formation of the contents of mineral veins.

which its equilibrium is incessantly disturbed. That power we conceive to be friction, generated by the unceasing oscillation of the tidal wave, which perturbs the electrical equilibrium, by which electricity is excited and constantly transmitted through the stratification of the earth; pressure generating friction, and friction producing pressure, so on from the selection and arrangement of the minutest microscopic atom on the sea shore, through the successive stages or ramifications of the repletion and formation of mineral veins, the up-heaving of the stratification into anticlinal ridges, on to the momentous event of a volcanic eruption. This is rendered the more manifest from the relative position of land and sea, and also from the rotation of the earth on its axis, which, in conjunction with the attractive and repelling influence of other planets, keep the tidal wave in every part of the globe perpetually battling with inertia, thus incessantly generating friction, which, in its turn, disturbs the electric agents: and if we are to consider that the influence of the heavenly bodies is of such a nature as to assist in effecting an unceasing oscillation of the tidal wave, by which friction is constantly generated in this, we see no reason opposed to the idea of the physical connection being reciprocal, and that the attractive and repulsive power of this, produces the same result in them, so that by that means a generating force is perpetually maintained in all. Sir John Herschell, in his Discourse on the Study of Natural Philosophy, thus remarks relative to the original mode of disturbance of electrical equilibrium, p. 333. "The most obscure part of the subject is no doubt the original mode of disturbance of electrical equilibrium, by which electricity is excited in the first instance, either by friction or by any of those causes which have been ascertained to produce such an effect:

analogies*, it is true, are not wanting; but it must be allowed that hitherto nothing decisive has been offered on the subject; and that conjectural modes of action have, in this instance, too often usurped the place of those to which a careful examination of facts alone can lead us."

It will be perceived, that the subjoined analogy is peculiarly striking, relative to the ebbing and flowing well at

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* "We will mention one which we do not remember to have seen noticed elsewhere in the case of a disturbance of the equilibrium of heat produced by means purely mechanical, and by a process depending entirely on a certain order and sequence of events, and the operation of known causes. Suppose a quantity of air enclosed in a metallic reservoir, of some good conductor of heat, and suddenly compressed by a piston. After giving time for the heat developed by the condensation to be communicated from the air to the metal, which will be thereby more or less raised in temperature above the surrounding atmosphere, let the piston be suddenly retracted and the air restored to its original volume in an instant. The whole apparatus is now precisely in its initial situation, as to the disposition of its material parts, and the whole quantity of heat it contains remains unchanged. But it is evident that the distribution of this heat within it is now very different from what it was before; for the air in its sudden expansion cannot re-absorb in an instant of time all the heat it had parted with to the metal: it will, therefore, have a temperature below that of the general atmosphere, while the metal yet retains one above it. Thus, a subversion of the equilibrium of temperature has been *bona fide* effected. Heat has been driven from the air into the metal, while everything else remains unchanged.

"We have here a means by which, it is evident, heat may be obtained, to any extent, from the air, without fuel. For if, in place of withdrawing the piston and letting the *same* air expand, within the reservoir, it be allowed to escape so suddenly as not to re-absorb the heat given off, and fresh air be then admitted and the process repeated, any quantity of air may thus be *drained* of its heat."

Newton Nottage, which is effected on much the same principle as that of a forcing pump or a steam engine. It is fully understood that the latter is dependent for its power, on the expansion of steam previously confined, which produces effects corresponding to its density; the force of which, if not maintained by a generating power, will diminish inversely as the cube of the volume increases. The probability is, therefore, that heat and electricity are the same, or one a modification of the other; consequently, the analogy strengthens, more than it detracts from, the view of friction generated by the tidal wave in overcoming inertia, being the agent by which the electric currents are set in motion and transmitted through the deposits of the earth.

There is a great "south down-throw" fault* running nearly parallel with the central anticlinal and the south outcrop of the measures. There is a rule by which miners are governed when indicating the direction of a fault. When it forms an obtuse angle with the floor or bed of the coal, or inclines from it, it is an "up-throw;" but when it forms an acute angle, and declines from it, it is a "down-throw;" and when it is perpendicular, it proves a source of great annoyance to the most experienced miners, there being no rule to be depended upon, by which its direction can be determined. It is not uncommon to find the coal on the off-side level with the working side, and it is invariably the case that when the coal is soft on one side, it is comparatively hard on the other. This south-down

* This fault is occasionally intercepted by a transfuse dislocation, by which it is shifted north and south of its usual or general line of direction, in some cases the shift being for more than a mile.

throw dislocation enters the Basin on the east, on the south rise of the coal measures, at Twyn y Barlum in Monmouthshire, crossing the Sirhowy River below Quarry-mawr, the Taff by Maes-mawr, the Ogmore River by *Velin Evan Dds* or Blackmill, the south side of Moelgelia Mountain and Garth Hill, on to Aberavon on the west, where it passes, like the anticlinal axis, under Swansea Bay, and, in all probability, runs, like the former, out of the coal measures in that direction. This fault is strongly developed on the surface between Swansea Bay and the River Taff, where the upper or Mynyddyslwyn beds of coal take ground, in one instance occupying a breadth of about 100 yards.

Near the town of Aberavon it passes two large north and south faults, throwing down the measures westward considerably. From Craig Avon, where these two transverse faults converge to a point, they extend northwards through Dinas Hill, crossing the anticlinal axis between Cwm Avon Works and Swansea Bay, one going eastward of Neath through the Gnoll Castle grounds, and the other close to the west end of the town. This may in some measure account for the variety of positions assumed by the strata in Dinas Hill, above the town of Aberavon. Indeed, the combined influence of so many conflicting forces, must have been, as they drew near the surface, necessarily attended with a multiplicity of contortions. From similar circumstances which have come under our notice in other parts of the Basin, we are of opinion that the parts near the surface only are contorted, owing to the inability of that part of the mass to sustain, with any degree of order, the immense pressure which must have been exerted in this district to produce the faults and anticlinal axis. The

latter heaved up the cockshot and black-pins at Baglan, which, as we have before stated, forms the barrier of division between the north and south troughs. The cockshot, which is the base of the Pennant or black-band series, is to be seen basseting south, near Baglan Hall, the residence of Griffith Llewellyn, Esq., and is followed in regular succession, in ascending order, by the outcrops of those beds of coal between that spot and Neath—clearly exhibiting the south edge of the main or north Basin, the centre of which is a little north of that town, from whence they are again seen rising to the opposite outcrop. In going south from Baglan to Pyle, we cross the basseting edges of the south Basin. A line from Llanelly, in Carmarthenshire, on the west, through the town of Neath, Navigation-house on the Taff, by Blackwood, to near Pontypool in Monmouthshire, on the east, would about represent the centre of the larger or main trough—and another, from a little below Quarry-mawr, in the Sirhowy Valley, Monmouthshire, on the east, through Bettws on to near Aberavon, on the west, would be near the centre of the south or lesser trough. Again, a line from Baglan, near Briton Ferry, on the west, through Newbridge in the Taff Vale, on to Velin-fach in the Sirhowy Valley, on the east, would be nearly the direction of Conybeare's anticlinal or elevated line of division between the two Basins.

The variety of contortions into which the measures have been thrown in the upper portion of Dinas Hill, near Aberavon, and to which we have just adverted, are not wholly confined to the South Wales Basin; there are similar instances to be met with in nearly every coal field. In the slate series underlying the old red sandstone they prevail to an almost incalculable extent. These, geologists

without exception represent as being twisted and contorted into every imaginable form, without the slightest hint at any alteration in their course downwards. On Park Tregunter and Hirwain Common, on the south outcrop of the basin, the coal and ironstone strata present a variety of contortions such as are met with in the slate series; but on following these irregularities for a depth varying from six to sixteen yards below the surface, we lose them entirely, and the strata then assume a regular order of inclination.

### DUDLEY COAL FIELD.

An eminent geologist* tells us that in the Dudley Coal Field the irregular dislocations in the primary strata are necessarily accompanied by dislocations which extend for considerable distances through the adjacent coal field. The most powerful fault ranges from north-east to south-west, the direction of its major axis. Two of these, running parallel to each other, produce a deep and narrow trough of eighty-four yards wide. The edges of this trough coincide precisely with the direction of its anticlinal axis.

### THE APPALACHIAN COAL FIELD.

Mr. Lyell, in his Travels in America, tells us that "the Appalachian chain of mountains consists of strata folded into a succession of concave and convex flexures, subse-

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* Sir R. I. Murchison.

quently laid open by denudation. The component rocks are of great thickness, all referable to the Silurian, Devonian, and carboniferous formations. There is no principal or central axis, as in the Pyrennees and other chains, no nucleus to which the minor ridges conform, but the chain consists of many nearly equal and parallel foldings, having what the geologists term an anticlinal and synclinal arrangement. This system of hills extends, geologically considered, from Vermont to Alabama, being more than one thousand miles, from fifty to one hundred and fifty broad, and varying in height from two to six thousand feet. Sometimes the whole assemblage of ridges runs perfectly straight for a distance of more than fifty miles, after which, all of them wheel round together and take a new direction at an angle of from 20° to 30° to the first. The bending and fracture of these beds is greatest on the south-eastern or Atlantic side of the chain, and the strata become less and less disturbed as we proceed westward, until at length they gain their original or horizontal position. On the eastern, or side nearest the Atlantic, the dip predominates, in consequence of the beds having been folded back upon themselves. The movements which imparted so uniform an arrangement to this system, must have been contemporaneous, or belonging to one and the same series, depending on some common cause. The greatest disturbing and denuding forces have evidently been exerted on the south-eastern side of the chain, and it is here that igneous and plutonic rocks are observed to have invaded the strata, some of which run parellel to the direction of the Appalachian chain, or north-north-east and south-south-west."

## THE EDINBURGH COAL FIELD.

Another instance of a like arrangement is to be met with in the coal field of Edinburgh, where we find the anticlinal axes and faults running parallel to each other, evidently exhibiting a uniformity of movements, governed by one and the same common law. A transverse section across this coal field corresponds with the same across the South Welsh Coal Field, the decrease in the thickness of the entire coal measures being in the same proportion as the diminution in the angle of dip or *vice versa*.

## THE DUHALLOW COAL FIELD.

There is also a coal field of a similar kind to be met with in the south of Ireland, and known as the Duhallow Basin, which, we are told by an eminent Irish geologist, is the most extensive in the British empire. On examining a part of this coal field, between two and three years since, in the vicinity of Kanturk, we found it to contain six beds of anthracite coal of a moderate quality, with two of black shale, resembling black-band, with some pins and balls of ironstone, resembling in appearance (with the exception of two or three) the poor ironstone in the South Welsh Coal Field. The great quantity of sulphur which this coal contains, makes it unfit for nearly every purpose but that of burning lime. This Irish field of coal is traversed by several anticlinal axes, with faults running parallel to them, dividing the whole mass into a series of troughs, which appear to have a much greater resemblance to an angular than a curvilinear form. The measures there

seemed identical with the lowest portion of the lower or ironstone deposits in the South Welsh Coal Field, and, the shale, which, in some cases, was in and over the limestone, &c., had a striking resemblance to that which is found in connection with the millstone grit on Pen-y-vai Common, near Bridgend; these measures, therefore, come under the denomination of the proper coal measures, which Mr. Conybeare denominates the carboniferous or great coal formation.

Here, then, we have the Dudley coal field in England, the Appalachian in America, the Edinburgh in Scotland, and the Duhallow in Ireland, with their anticlinals and faults running parallel to each other, all more or less tending to prove their subjection to the same leverage of pressure, depending upon one common cause harmonising in all its results. *

In a prize treatise on the Mineral Basin of South Wales, written by Mr. Booker, we find the following paragraph:— "The deepest part of the Mineral Basin," say the highly-talented and accurate geologists of England and Wales, "is in the neighbourhood of Neath, which is near its centre, and a little west of it; the lowest strata are nearly 700

* In a paper read at the meeting of the Geological Society, in November last, by Professor H. D. Rogers, "A comparison of the structural features of the Appalachian of the United States with those of the Alps and other disturbed districts of Europe," this universal arrangement of the faults and anticlinals was corroborated. This is, perhaps, the more satisfactory, from the probability of that gentleman being unaware of our having drawn attention to this circumstance some twelve months before.

fathoms lower than the outcrops of some of the superior strata in the more hilly parts of the district."

Sir H. De la Beche tells us, that the deepest part of the Coal Field is in the neighbourhood of Llanelly, and that the entire thickness of the coal strata, in a section from Caswell Bay on the south, through Penllergaer to the north, is 11,000 feet on the south, and 8,000 feet on the north rise, making a difference between the two basseting edges of the measures of 3,000 feet; which is accounted for by him, by taking away 1,400 feet for the Gower shales and sandstone, but slightly shown on the north crop. This would leave 1,600 feet for the remaining difference in the beds above, being a decrease of 1 in 60. Including the Gower shales the decrease would be about 1 in 31,—even in that case not exceeding an angle of 2°. From this view of it we conclude that Sir Henry considers that the measures gradually decrease in thickness from south to north, and that the entire thickness in the centre of the trough is considerably more than on the north outcrop. This makes a considerable difference between this distinguished investigator and those who have preceded him, as to depth and local position; nevertheless, it must be remembered that when those geologists examined the Coal Field, which was about thirty years since, a little west of Neath was then considered to be its deepest part, but the experience of so many years of active mining operations has further developed its resources and true position.

Eastward of Neath, and in that rich maiden district between Briton Ferry on the west and the River Taff on the east, the entire thickness of the Pennant, and lower or ironstone measures, from the upper tilestone rock down

through the bottom beds of ironstone, would average on the south rise of the south basin about 4,800 feet. The vein of coal next above the upper tilestone in Cefn-morfydd Hill, immediately to the east of Neath, is the same as the middle Bettws vein and the one at Llantwit-vardra, near Llantrissant, above the same rock; consequently, sections taken at six or eight places between those points would give about the same average thickness as before stated. To the east of the River Taff, the lower or ironstone and Pennant measures begin to thin out very gradually, and yet perceptibly, on the south and south-east rise; and the upper or Mynyddyslwyn beds, (the lowest seam of which being the same as that above the upper tilestone at Llantwit-vardra), show an increase in number and entire thickness.

This may be accounted for by the near approximation of the anticlinal axis to the south, south-east, and east outcrops of the coal strata in that direction, where it runs out of them into the carboniferous limestone and old red sandstone, as well as to that of the south lateral pressure, with which the anticlinal axis becomes united in the Usk Valley, which together consolidated the measures, (consisting of the greater part of the Pennant, and the whole of the lower or ironstone series,) considerably more within the range of their maximum pressures in that direction than to the west and thereby made room for a greater number and entire thickness of the Mynyddyslwyn beds in the main trough to the north. The district at the western end of the Coal Field, between the town of Neath and a little beyond Llanelly, west of which place the upper or Mynyddyslwyn veins show a decrease in number, &c., instead of an increase, as we find them to the east of the

River Taff, must therefore be looked upon as containing the greatest number of beds of coal and total thickness, and a pit sunk at or near Penllergaer would have to go down nearly 11,000 feet to pass through the bottom beds of shale, according to the curvilinear theory. The beds of coal distinguished as the Penllergaer, to the west of Swansea, which are known to the east as the upper or Mynyddyslwyn, with the upper tilestone as their base, basset out or disappear one after the other in an easterly direction, and on arriving at Tonmawr, above Neath on the east, there are but two left which we can class with that series. These "lose" and "take ground" occasionally between that and the River Taff, passing over the anticlinal axis from Tonmawr, in the north trough, where one is worked for export by Weymouth and Green, over into the Llynvi valley, below Maesteg, in the south trough, where the under bed is also worked by Sir Robert Price, Bart., M.P., continuing at intervals to cover the Pennant measures between that and the River Taff; and at Dehewydd, in the parish of Llantwit-vardra, there is a working upon the lower bed, close by the roadside leading to Treforest. They cross over the anticlinal axis again by Cefn Eglwys Ilan, into the north trough, and occupy the high grounds in the parishes of Gellygaer, Bedwellty, and Mynyddyslwyn. We have now two sections before us which were made some few years ago from workings, &c., representing all the faults which had been met with up to that time, in this upper series, over a considerable area to the east of the River Taff. One extends from Llanvabon church, in the county of Glamorgan, on the west, to Pen-rhewfrank, near the British Iron Works, in the county of Monmouth, on the east. The other ranges from Mamhole village, in the parish of Bedwellty, on the north, to the

Church farm, in the parish of Mynyddyslwyn, on the south. A line drawn from the lowest position of one of the beds, in the section to the north outcrop, will be found to coincide with the angle of inclination of the whole bed, and meet the same at the outcrops, notwithstanding the numerous deviations and disruptions of the bed in its upward course. It is important to observe that this is a case in point—that however much the strata may be interfered with by dislocations between the centre of the troughs and the outcrops, the result is the same as if they pursued one undeviating rise or fall without any interception by faults.

In a former part of this treatise we have frequently adverted to the Cockshot Rock and black-pins ironstone. This Cockshot occupies rather a central position on the south rise of the coal measures, in the district between the River Taff on the east, and Swansea Bay on the west, and is followed, at some distance beneath, by the black-pins ironstone. The connection existing between these two marked and peculiar deposits, throughout the Coal Field, is of the greatest importance to the geologist and surveyor in classifying the strata of one locality with those of another; indeed, without the aid of some such well known feature, it would be a matter of considerable difficulty to arrive at a correct comparison. From Briton Ferry, Swansea Bay, in a westerly direction, the Cockshot ranges considerably under the centre line, owing to the increased number of the red-ash or Penllergaer beds, in which position it continues until the latter beds lose ground to the west. On wheeling round north, through the mouth of the Gwendraeth Valley and by Pembre Mountain, it gradually gains a more central situation, which

it retains for a short distance to the east, when it again passes some distance under, until it reaches the Aberdare district; thence it continues more central to the east outcrop, where it once more passes under, continuing that position along the south-east outcrop, and, as it approaches the point from whence we started, it gradually again reaches a more central position, forming, with the black-pins ironstone, two belts, as it were, with few intermissions in cases of large dislocations, &c., around the whole area of the Coal Field. They are here and there thrown up by the anticlinal axis, from the back of which they dip, with two or three exceptions, north and south, at an angle, as we have before stated, of from 10° to 20°, and rise to the south outcrop, at an angle of about 45°, but for the extreme north, at an angle of about 10°. The Cockshot is to be seen exposed along the back of this ridge at Pont-y-prydd, Cwmddu, Maesteg, Cwm Avon, and Baglan, and at the latter place the measures dip at an angle of about 40° to the centre of the north trough.

There are two more lines of elevation in connection with this Coal Field, running, in a measure, parallel with the centre one, and traversing the mountain limestone and old red sandstone on either side of it, and are known as the north and south lateral pressures. The south pressure, in its eastern course seems to turn a little north near Newport, Monmouthshire, following, as it were, the direction of the outcrops of the coal measures in that quarter. The north line of pressure traverses the north edge of the Coal Field, but we have not as yet ascertained whether it follows the outcrop of the measures around to the east; though we are strongly disposed to think it does for a short distance. From observations made in different parts, on

the course pursued by the anticlinal lines of the Secondary Series, one with the other, we are of opinion that if we take four lines of latitude and four lines of longitude on a globe, and alternately contract the distance between two of the latitudinal lines at every alternate line of longitude, they would form a figure resembling that presented by these axes of elevation, one apparently governing the other in its direction.

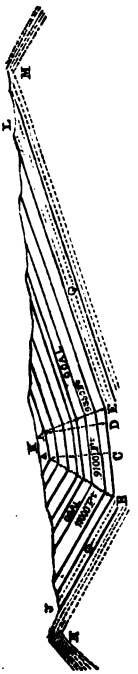
We must consequently look upon the Coal Field to the east of Swansea as being, in a measure, surrounded by two immense lateral pressures, one acting north, and the other south, with the anticlinal axis through the centre, or a little south of it—the latter appearing the most powerful, and uplifting the coal and ironstone strata, throughout its range, into an elevated position, whereas, if it had not been for the intervention of some such power, the measures would be many hundred yards deeper. The anticlinal axis has thrown the upper or Mynyddyslwyn beds, which previously covered it, into the troughs on either side, according to local circumstances, and thereby imparted an additional weight to the troughs, particularly the southern, of which it was itself deprived. As the central anticlinal or upward pressure attained a higher level than the southern, the force of the superincumbent weight was directed most effectually in and to the north of a line diagonal to a square of the mass between the two elevations. This materially compressed the strata in that direction, and leaving the measures to the south, above this diagonal line, to the power of the south lateral pressure, which, with the assistance it received from the diagonal weight acting in the direction, (now the foot of the dip from the south outcrop,) tilted the strata (in the

thickness of which a considerable expansion at the same time ensued) to the south of this line into a high angle of inclination, on that side was relieved, and forced the whole, in their dip or transverse direction, into a form much more resembling an angle than a curve. From this arises the steep dip and greater thickness of strata on the south rise, and the flat position and lesser thickness in the centre of the trough. This also serves in some measure to solve the hitherto unaccountable phenomenon of the coal being of a hard and compact structure in the centre, as well as on the north rise of the Coal Field, and of a soft and friable nature on the south rise of the same. This principle is very clearly demonstrated in the Llynvi Valley, below Maesteg.

Mr. Conybeare's anticlinal axis, or elevated line of division between the south and north trough, passes out of the coal strata near Swansea; consequently we have only one basin to the westward of that place, which is a continuation of the north trough; a section from the Mumbles on the south, through Penllergaer to the north, would be, therefore, within the limits of the Field, where the whole of the coal measures are embraced by one trough, hedged in by two lines of pressure, one north, and the other south of it. On the south outcrop of this trough, and in a line nearly south from Penllergaer, the perpendicular depth of the entire strata is, as we before stated, according to Sir H. De la Beche, 11,000 feet, and on the north outcrop 8,000 feet, making a difference between the two outcrops of 3,000 feet. This diminution is explained by that eminent geologist, by a gradual decrease of thickness from the south to the north outcrop; but according to the angular theory, which is based on a common and simple principle,

the difference is accounted for in such a manner as must appear striking in the extreme, and proves, in its workings, the entire depth of the coal measures throughout the greater part of the coal-field to be nearly one-third less in the centre than what it is according to the curvilinear principle —the view taken of it by all our geologists—and yet corresponding in its results at the outcrops.

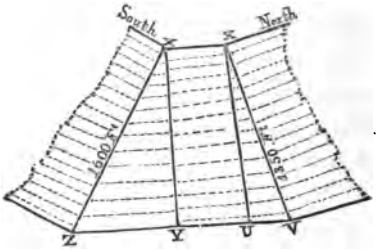
[Diagram No. 3.]




A,B,C, is a right-angled triangle. A,B, the hypothenuse, at right angles to the "strike" of the measures, which dip from the south outcrop at an average angle of from 34° to 35°, and equal to a depth of 11,000 feet. A,C, is the perpendicular, at right angles to the position of the strata in the centre, and equal to a depth of 9,100 feet, being about 1,900 feet less than on the south rise. A,D,E, is another right-angled triangle. A,E, the hypothenuse, and at right angles to the strike of the measures from the north outcrop, the average angle of dip being about 12°, and equal in perpendicular depth to about 9,350 feet, which is 250 more than in the centre, and 1,650 feet less than on the south rise.

Again, X,Y,Z, is a right-angled triangle, and X,Z, the hypothenuse, at right angles to the south dip of from 34° to 35°, and equal in depth to 1,600 feet (the depth of the Gower shales and sandstone on the south rise, in the Caswell Bay and Penllergaer section), and X,Y, the perpen-

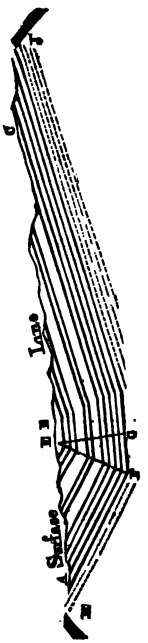
[Diagram, No. 4.]




dicular, equal in depth to nearly 1,300 feet. X,U,V, is another right-angled triangle; X,V, the hypothenuse, at right angles to the strike of the shales, &c., from the north crop, and equal in depth to about 1,350 feet, or 250 feet less than on the south rise. It appears that these shales are but slightly shown in the Caswell Bay section, on the north crop, for which, Sir Henry De la Beche makes an allowance of 1,400 feet; but this theory will not admit of more than 1,350, which, if the shales, &c., proved on the north rise, would be their thickness. Then, 1,350 feet added to 1,650 feet, the difference between A,B, and A,E, or the entire thickness of the coal measures on the north and south outcrops, gives 3,000 feet, which corresponds precisely with the difference in Sir Henry De la Beche's section. Again, by taking X,V, which is equal to 1,350 feet, the thickness allowed for the absence of the shales, &c., on the north outcrop, in compliance with this principle, from A.E, which is equal to 9,350 feet, the entire depth of the measures on the north outcrop, we have a total thickness of 8,000 feet, which again agrees with the depth given in Sir Henry's section:—or, as the hypothenuse of a right-angled triangle is to the perpendicular, (the hypothenuse being at right angles to the strike of the strata

from either crop, and the perpendicular at right angles to the strata in the centre,) so is the perpendicular depth of the strata, on either rise, to the same in the centre of the Coal Field. Some may be disposed to reply, " How is it possible to apply a theory of this kind to measures so very frequently intercepted by faults?"—In the former part of this treatise we drew attention to a transverse section of the upper or Mynyddyslwyn series, made from actual workings, and notwithstanding the multiplicity of dislocations intervening between the lowest position occupied by the strata and the outcrops, the result is precisely the same as if they had continued one uninterrupted rise from point to point.

[Diagram, No. 5.]




In Sir Henry De la Beche's section of the strata from Caswell Bay on the south, through Penllergaer to the north, to which we have applied this theory, there is another beautiful exemplification of that extraordinary feature in the Coal Field—of the coal being hard and compact on the north rise, and soft and friable on the south; but here we have the additional phenomenon of its being anthracite on the north, and bituminous on the south. A,B,C, represents the south outcrop, centre, and north outcrop of the measures in this section; and E,F,G, is a right-angled triangle; E,F, the hypothenuse, or line of division between the anthracite and bituminous quality of the beds of coal, all to the south of E,F, being bituminous, and all to the north

anthracite, with the exception of a few of the upper beds; and H,I, the north and south anticlinals, or lateral pressures. Here again we find the north pressure to have attained a somewhat higher level than that on the south, consequently the immense pressures which were put in motion on this colossal mass from above, underneath, and laterally, at one and the same time, to heave the strata out of their original horizontal position* into the form we now find them, operated on the mass, in their most effectual manner, in and beneath the direction of the line, E,F, and leaving that part of the mass above and to the south of this line to the power of the south pressure, which was materially weakened in its effect by the north pressure acting in that direction upon it, which is now the foot of the dip of the strata from the south outcrop, or line of division

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* The following simple rule gives the original thickness of the coal measures in this section:—No. 5 Diagram.—Half the difference between the hypothenusal line E,F, and the perpendicular E,G, the hypothenuse at right angles to the dip of the strata from the south outcrop, and the perpendicular at right angles to the plains of stratification in the centre, an expansion on the south rise of one-fourth, and a compression of the same extent in the centre, which, together give one-half the difference between E,F, and E,G, and equal to the original thickness.

| | FEET |
|---|---|
| South rise present thickness or E,F, ..... | 11,000 |
| Centre of the trough, present thickness or E.G, ..... | 9,100 |
| | 2 \| 1,900 |
| | 950 |
| Original thickness of the mass, prior to its subjection to the pressure of the anticlinal levers ..... | 10,050 |

This rule is applicable to all the stratified deposits from the coal measures down to the granite.

E,F. Hence arises the steep dip, and the soft and bituminous nature of the coal, on the south rise, and the slight dip and anthracite quality of the coal on the north; and it also leads us to the conclusion that the change from bituminous to anthracite was caused by intense pressure giving rise to friction, which set other elements in motion upon the mass, and which, in their turn, forced the volatile matter, in a state of gas or otherwise, through the pores of the beds of coal, evidences of which are still retained by the anthracite, sufficiently conclusive of its once bituminous nature, and that the change resulted from a subsequent movement.

Sections taken transversely or across the Coal Field from north to south, between Llanelly in Carmarthenshire, and the Sirhowy Valley, in Monmouthshire, would be, in their results at the outcrops, equally corroborative of this theory. The importance of this to the Principality must appear evident to all, reducing, as it does, the entire depth of the coal measures in the centre of the Basin (where they dip from the south outcrop at an angle of about 45°, including nearly the whole of that part of it to the east of Neath,) to nearly one-third less than what it has been hitherto considered by geologists, and borne out, as it is in its results, *at the outcrops*, by a section made under the favourable auspices of the Geological Survey of Great Britain. We find in a paper published in the Reports of the House of Commons for 1830, furnished by an able and eminent geologist, that the minerals of the South Wales Basin are represented as not available with a profit at a greater depth than 200 fathoms. This calculation falls considerably short of present operations. We are informed that the Monkwearmouth pit, in the north of England, is

prosecuted at a depth of 299 fathoms, which is 99 fathoms, more than the statement in the Report. We should not therefore be far wrong, in this instance, by considering the depth workable with a profit, at 600 yards. This would, according to the curvilinear theory, embrace little more than the Pennant series within the precincts of the troughs, from Neath, in Glamorganshire, to near the eastern extremity of the Basin, and again to the west from Neath to a little beyond Llanelly, in Carmarthenshire, a little more than one-half of that series would come within working range of that depth, consequently the whole of the lower or ironstone series, which is well known to be the most valuable the Field contains, is, for full one-half of its area to the east of Llanelly, in compliance with the views of geologists, at too great a depth to be made available with a profit; but, according to the angular theory, as the hypothenuse of a right-angled triangle is to the perpendicular, (the hypothenuse being at right angles to the strike or dip of the beds from either outcrop, and the perpendicular at right angles to the position of the measures in the centre,) so is the perpendicular depth of the measures on either rise or dip to the same in the centre of the Coal Field. The whole of the lower or ironstone series to the east of Neath, with the exception of a narrow strip in the south trough in the Llynvi Valley, which is about the deepest part of the Field in that direction, could be reached at a depth not exceeding 600 yards, which is about the depth of the Monkwearmouth pit (for example). The entire thickness of the workable coal measures on the south rise of the Coal Field, a little west of Margam Abbey, is within 3,800 feet, consequently the thickness in the centre in this case would be, in compliance with the angular theory, about one-third less, or 2,534 feet, out

of which there is to be deducted the difference of level between the position of the upper bed, in the centre of the Coal Field, and that of the outcrop of the lower bed in this district,—say 700 feet, which would leave a depth in the centre of about 1,834 feet beneath the level of the outcrop of the latter. A pit sunk on Margam Moors* on a level with the south crop of the lowest bed to a depth of 1800 feet:—the extent herein considered of profitable operations would be within working range of the workable coal beds, to the north of this point, and also to the east, with the exception of a narrow strip in the Llynvi Valley, which is, as we have before stated, about the deepest part of the Field to the east of Neath, and a very large proportion of the measures westward of Neath, would come within that range.

This plan, though new, is not without its advantages, and we have no hesitation in stating, from calculations made in the matter, that it would be found to be attended in some cases, particularly in extensive iron establishments, with greater economy than what at present exists at many works. By having the blast-furnaces, &c., erected immediately in front of the pits, which pits should be of sufficient magnitude to carry on extensive operations, the whole consumption of coal, ironstone, and limestone, could be landed out of the pit's mouth into the yards at the back of the works, doing away, in a great measure, with the expense of haulage and tonnage, which is, in some cases, so detrimental to the prosperity of works having a

* A pit has been commenced in this locality subsequent to the First Edition of this Treatise.

portion of the requisite materials at a considerable distance from their sites. We are acquainted with two or three instances of works being a distance of 20 miles from the shipping port, and about 15 miles from the nearest available limestone quarry. In such cases the expense of haulage and tonnage, &c., for a few years, coupled with that requisite for opening works necessary to an extensive iron manufactory, would more than compensate for sinking the shafts, and driving across the measures, according to the proposed plan, to gain resources for works of equal magnitude, to which we may add the more than probable chance of meeting with considerable masses of the brown Hematite iron ore, which is known to exist in great quantities in and about the limestone on the southern edge of the Coal Field.

The rapid strides which have of late years taken place in the increase and improvement in the manufacture of iron, &c., in this immense treasury of mineral wealth, (a list of which we subjoin) are very striking, and perhaps unexampled:—

| Date. | No. of furnaces. | Quantity of pig iron made. |
|---|---|---|
| 1823 | 72 | 180,827 Tons. |
| 1830 | 110 | 270,407 „ |
| 1846 | 188 | 500,000 „ |

If we may judge from past and present appearances, this is as yet in its infancy, and if we turn to the future, the very advantageous and convenient arrangements of its mineral deposits, places the South Welsh Coal Field in a position so peculiarly favourable as to be beyond the reach of competition from any like deposit which has been

hitherto discovered in the known world. Then, a principle so simple and unerring in its application, proving as it does by its calculations, the more than probable fact of nearly the whole of the coal and ironstone measures in this rich depository (one half of which has been hitherto supposed impracticable), to be within working range of a shaft or pit little exceeding in depth that now in operation in the north of England, must in some degree, claim the attention of all interested in the prosperity of this country, and more particularly when it is no less a fact than a statement, that Great Britain is in a great measure indebted for its unequalled commercial wealth and national importance to the simple, but invaluable mineral substances, coal and ironstone. While nations have been impoverished, and nearly ruined, our own little island has nobly and gloriously withstood the concentrated Powers of nearly all Europe, and has arrived, amidst it all, at a degree of prosperity unexampled in the annals of the world.

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## A DEMONSTRATION OF THE SUBSIDENCES IN THE DISTRICT INTERVENING LLYNVI AND PENLLERGAER.

Before we proceed with this subject, it will be necessary to offer a few remarks on the anticlinal levers,—the agents instrumental in effecting the subsidences.

### ANTICLINALS.

The various views which have been entertained on the

cause, the direction, and the effects of these elevating forces on the stratification of the earth, render any subject connected with them of more than common interest; but as our observations in this Treatise are more particularly confined to the South Welsh Coal Field, (although the principles herein explained is applicable to any other,) it would be irrelevant to extend our remarks on them in this instance any more than is necessary to bear out our views beyond the limits of its deposits.

The Coal Field of South Wales is, as before stated, divided into two elongated troughs with a ridge between, known as the anticlinal axis or saddle-back. Besides this there are two more lines of elevation or pressures traversing the old red sandstone and carboniferous limestone on the north and south side of the outcrops of the coal measures. These three lines of elevation or pressures may be considered therefore to be within the limits before mentioned, and the chief agents in the production of the structural changes which have ensued in the stratification embraced by them.

We would also draw the reader's attention to what has been previously observed, that four lines of latitude and four of longitude on a globe, with a contraction of the distance between two of the latitudinal lines at every alternate line of longitude, would form a figure somewhat resembling that presented by these axes of elevation, one apparently governing the other in its direction, and whenever two or more of these lines converged to a point or became united, as was occasionally the case, the intensity of action increased materially. They are, in fact, the channels by which that apparently inexplicable principle

or property of matter—electricity*, when violently excited, was conducted to the weakest point of resistance in order to restore the equilibrium.

The angle of radiation of these forces from the direct line does not appear to exceed an angle of 45°. This maximum of radiation diverging east and west from

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* Electricity is an imponderable property of matter pervading every substance in and surrounding the earth. It has a positive and negative influence. Electricities of the same kind repel; those of opposite kinds attract each other; their repulsive and attractive powers are assumed to be equal at equal distances. It appears to be that principle or inherent property of matter which preserves the earth a sphere, and guides the planets in their course, and which, on being violently disturbed, restores the equilibrium at any cost. It produces lightning and thunder in the atmosphere—earthquakes and volcanoes in the earth. The prognostication of a volcanic eruption is a fissure or dislocation in the stratification of the earth, produced by electricity on being violently perturbed, to restore the equilibrium. These fractures are instantaneously followed by powerful gushes of atmospheric currents to a common centre or centres, the converging points being the apertures effected by the electric agent. These currents unite with the electricity, and when the combination is of sufficient intensity to generate combustion, the product bursts forth in all the awful grandeur of a volcanic eruption. This restores the equilibrium and all proceeds as before. Electricity appears to be, therefore, to inorganic substances, as blood is to the body, and those who have experienced a stoppage of the circulation of the blood, would probably form some notion of this powerful agent in equilibrio or when confined, and it, like the blood of the body, requires a forcing power to keep it in a state of perpetual circulation or excitement, in order to render it active, and that that power is (as we have before stated under the head of Electrical Equilibrium) induced by the oscillation of the tidal wave, from whence it passes, to effect its wonderful operations, from the arrangement of the minutest molecule, through its many successive stages, the upheaval of the strata into anticlinal ridges, &c., on to a volcanic eruption.

a straight line would readily suggest, without a strict examination, that there was no degree of parallelism maintained by them in their directions, as such would shew the anticlinals of the same zone of deposition, taking a course in one district at nearly right angles to a continuation of the same in the next, and yet the extreme point of divergence from the direct line would not exceed an angle of 45°. This may, it is very probable, be the cause of the difference of opinion existing amongst geologists relative to the direction taken by the anticlinal ridges.

The central anticlinal and south lateral pressure diverge from a common centre in the Usk Valley, to the east of the South Welsh Coal Field, and apparently converge or become united again in Carmarthen Bay at the west end of the same.

We have not been able to ascertain with certainty that these two anticlinals amalgamate in Carmarthen Bay on the west,—the waters of the Channel place that beyond the reach of ocular demonstration;—nevertheless, if we trace the direction taken by the south lateral pressure through the Vale of Glamorgan, there appears manifest reason to assume that they unite a little west of the Worm's Head. Moreover, when it is considered that the intensity of action has been materially increased in that direction, in order to force up the old red sandstone through the carboniferous limestone into view, so near the south outcrop of the coal measures on the western promontory of the Peninsula of Gower, the hypothesis that these two forces merged into one in Carmarthen Bay is rendered almost certain, and that the uplifting power was thereby so

increased in intensity as to form at the converging point a dome-shaped elevation or a ridge somewhat approximating thereto. This separated or detached the coal measures of the Pembrokeshire from those on the Glamorganshire side of the Bay, and caused the coal strata to rise to, or dip from this elevation, east and west,—a position favorable for working the beds from either side. If we follow these two lines of elevation to the Usk Valley in Monmouthshire, at the east end of the Coal Field, we shall find that where they converge to a point in that district, the same circumstances have prevailed, as the beds of the Silurian system are there to be observed penetrating or rising into view from underneath the old red sandstone, in the same manner as the old red sandstone protrudes through the carboniferous limestone on the western promontory of the Peninsula of Gower; and the Coal Field of the Forest of Dean has been detached from the mother mass by the same law which separated the Pembrokeshire from the same on the west. The greater distance between the central anticlinal and south lateral pressure to the east, and the considerable angle of divergence presented by the latter from the point of amalgamation in the Usk Valley, in some degree account for the extensive distribution of the old red sandstone in that direction, and its gradually-contracted dimensions, as these elevated ridges approach each other in the western district.

This also accounts for our finding many of the coal beds absent, or diminishing in number in the south trough, on approaching the points of amalgamation of the central anticlinal and south lateral pressure at either end, but more particularly that of the western end of the Coal Field. These two powerful pressures must have had a tendency,

on approaching each other, to force out some of the upper beds, (especially those easily deprived of their adhering qualities by the combined influence of air and water, which quickly worked their way through the splits and cutters, and the outcrops, and into the fissures produced and laid bare by the anticlinal pressures,) which were shortly broken up, and afterwards swept away by the mountain torrents into the neighbouring channel; whilst the beds which became more immediately under the control of these opposite forces, or beneath a certain line of diagonal pressure, suffered more or less the weight of compression in proportion to the extent and direction of the power they were exposed to. Hence it is that the strata now occupying the upper part of Dinas Hill by Aberavon, appear, from a comparison with the beds in the surrounding district, to those unacquainted with the changes produced by these powerful agents, to superimpose on beds with which they have, in their present position, no connection whatever, as the former strata have passed away and the present measures have taken their place. These forces maintained the same devastating influence on the coal strata to the west and opposite the town of Swansea; the central anticlinal and south lateral pressure approached each other so very nearly, as to devastate the whole of the coal measures down to the base of the millstone grit, the highest stratum passing over the central anticlinal ridge into the north trough in the Bay of Swansea, being the carboniferous or mountain limestone.

The same circumstances appear to have attended the thinning out of the measures in the south trough to the east. We should perhaps mention the reduction in num-

ber and entire thickness of the coal deposits in that direction, and the distance from the Cockshot down through the lower measures of ironstone has been reduced to something less than 500 feet, which is about 1500 feet less than in the Ogmore district, near the longitudinal centre of it; and yet the same strata on the north rise of the north trough present little variation in their entire thickness, from the Sirhowy Valley in Monmouthshire on the east, to near Llanelly in Carmarthenshire on the west. We consider, therefore, that the coal measures in the south trough, have not only decreased in thickness to the extent previously observed, in compliance with the amount of pressure they have been subjected to, but also in going east or west, from the central district, beds of coal, clay, shale, and rock, have been forced out by the anticlinal pressures, as they rose one after another, or rather as they became within or above the line of division, separating the diagonal weight, acting upon the strata between the central anticlinal and south lateral pressure, from the line of lateral movement, forcing away the beds within its range.

These agents have had a greater or less influence on all the series of stratification which compose the crust of the earth; and may, perhaps, be ere long found to account for various phenomena which are at present attributed to other causes.

We shall now proceed with our notice of the subsidences arising out of the anticlinal pressures, on the coal measures in the district between Llynvi and Penllergaer. We have previously stated that the Coal Field to the east of the Town of Swansea, has been traversed by

three anticlinal pressures, one north and one south of the outcrops, or north and south basseting edges of the coal measures, with another taking a direction somewhat south of the centre: the latter uplifting the coal strata within its range into gable-shaped positions, from the apex of which they now incline north and south. The angle of inclination presented by the measures from either side of this anticlinal ridge varies materially, between Baglan on the west and Maesteg on the east. At Baglan the angle of dip for the centre of the north trough is about 40°, but near Maesteg it is little more than 10°. It has often been a matter of consideration to us, wherefore the strata should strike from the apex of the central anticlinal to the north at an angle of 40° in the locality of Baglan, and little more than an angle of 10° in the same direction in the Llynvi district, some few miles to the east; and until some few years back, we were unable to arrive at any fixed determination on the subject.

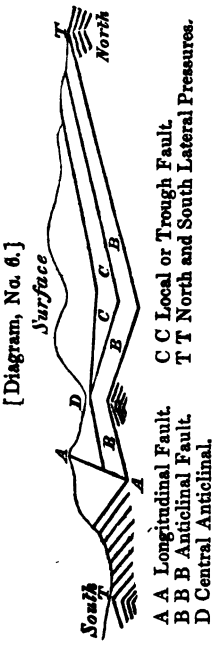
This difference in the inclination of the coal strata in these districts, appears hitherto to have escaped any particular notice, as all our geologists have passed it over without a single comment; but from its relative connection with the numerous changes which have ensued in this part of the Coal Field, it has nevertheless a very weighty claim on our attention. It is on the north outcrop of this district, where we find the coal to have been changed from bituminous to anthracite, the modifying cause being from the former to the latter, and it is here, where the coal strata begin to shew an increase in number and entire thickness, which at Penllergaer (south rise) give a total thickness of distinct additional deposits, of about 3000 feet over that in the Llynvi district.

The information hitherto communicated to us, with regard to the dislocations and subsidences which have taken place in the coal measures between Llynvi and Penllergaer, appears to have only rendered the classification of the strata in this district the more complicated. So manifest does this present itself to our notice, that it is scarcely possible to find two persons, geologists or others, who entertain the same opinion respecting them. Then, the necessity of having a principle that may tend to clear up the mystery which now hangs over this part of the Coal Field, must be obvious, and especially to those interested in its future prosperity.

An examination of the faults and of the variation in the angle of dip in the district under notice, arising out of the central anticlinal and the north and south lateral pressures, leads us to infer, (however, features are certainly in favor of the deduction,) that they passed from west to east. Assuming such to have been the case, it is quite clear, from the inclination at Baglan, which is about 40° from the apex of the central axis of elevation for the north trough, and again to the east in the Llynvi district where it is not more than 10° for the same, that as this upheaving power found its way out of the carboniferous limestone into the coal measures opposite the Town of Swansea, the additional counteracting pressures of the coal strata would have (if considered an elevating force) in some degree affected it; nevertheless, from the fact of the high angle of dip presented by the strata at Baglan and Cwmavon, it is sufficiently evident that it maintained the same maximum of elevating influence, or nearly so, on the mass opposed to it through those places from where it entered the coal measures near Swansea; but on reaching the head of the

Llynvi Valley, where it became immediately under the entire series of coal strata in the Coal Field, and which at Baglan and to the west acted upon a large proportion of them laterally, its uplifting powers were materially altered by the increased weight of the additional deposits (equal to several thousand feet more than it had to contend with in Baglan), so as to reduce, by the production of an increase in the extent of the longitudinal fault running parallel to it, the angle of dip, from 40° down to 10°. Contemporaneously with this, the north and south anticlinals acted, but as regards their effect on the coal strata, we may consider them north and south lateral pressures, as they have not passed immediately under the coal strata like the central anticlinal, but traversed the old red sandstone and carboniferous limestone on either side. As the south lateral pressure brought its influence to bear on the coal measures in the south trough to the east of Swansea, which to the west were without its limits or destroyed, it tended, with the diagonal weight of the central anticlinal which acted in the direction, now the foot of the dip from the south outcrop, to force the strata on that side into a steep angle of inclination averaging, between the River Ogmore and Swansea Bay, about 40°, sometimes more and at others less. These two forces, together with the north lateral pressure, resulted in extensive dislocations and subsidences, though differing from each other in extent and position, yet all accessary, in greater or less degree, to the production of the wonderful changes which have occurred in the stratification they traverse.

As the view we are about to explain is original, it will be here necessary, in order to render the subject as intelligible as possible, to distinguish those faults or dislocations according to their respective bearings on the mass.

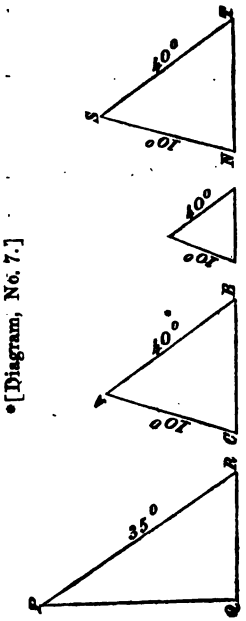



A A we shall denominate longitudinal faults as they are mostly found to range parallel or nearly so to the outcrops, or at right angles to the inclination of the strata. B B B, anticlinal faults. These invariably extend through one or more anticlinals as the case may be, and separate the entire mass transversely throughout their extent. C C, local or trough faults, being confined to one or other of the troughs according to local circumstances, and like the latter take a transverse direction.

A line drawn from the south outcrop of the south trough by Taibach, crossing the central anticlinal by Baglan, through Neath Abbey near the Town of Neath, to the north outcrop, would be near the centre of the district, where these subsidences giving an increased thickness of deposits of upwards of 3000 feet at Penllergaer over that in the Llynvi, have occurred.

Having, we conceive, pretty well prepared ourselves for the subject under notice by what has been previously advanced, we shall now proceed in as brief a manner as its nature will permit, to explain a principle by which the extent of those dislocations may be ascertained, and a correct classification of the measures intervening arrived at, and which can be applied with equal success to all the stratified rocks from the coal measures down to the granite;

but, as we have previously observed that our observations in this treatise are more particularly confined to the South Welsh Coal Field, it would be, therefore, unnecessary to extend our remarks beyond its deposits. We, however, trust that the main principles of the theory will be placed before the reader in such a manner, as to enable him with a knowledge of geology, to apply it to any other district. The following diagrams will probably prove of assistance in rendering more intelligible the explanations of the subsidences, &c., which have ensued in the district between Llynvi and Penllergaer.




[Diagram, No. 7.]

The line A,B, represents the vertical thickness of the coal measures, from the upper tilestone (by allowing about 3,000 feet from the Cribwr Fach vein of coal to the limestone) down to the carboniferous limestone, on the south rise of the south Basin, extending from the Llynvi Valley on the north to near Pen-y-Vay village on the south, and equal to a depth of 8,000 feet, with an inclination to the north of about 40°. A,C, the entire depth of the same near the apex of the central anticlinal or saddle-back to the north in the same district, and equal to a depth of about 6,250 feet, dipping from

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• The degrees attached to the diagrams give the inclination of the strata in the districts to which they refer, and to which the lines S,T,

the apex of the central anticlinal into the north trough at an angle of about 10°. S,T, the depth of the same on the south rise of the north trough in the vicinity of Neath or Baglan, and equal to a depth of about 8,000 feet, rising south from the north trough for the anticlinal ridge at Baglan, at an angle of about 40°. P,Q, the depth of the whole of the coal measures down to the carboniferous limestone in the centre of the trough Penllergaer, where the strata are nearly horizontal, and equal to a depth of 9,100 feet. P,R, the depth of the same on the south rise Penllergaer, dipping for the trough at an angle of about 35°, and equal to a perpendicular depth of 11,000 feet. Then the difference between A,B, and A,C, added to the same between S,T, and S,N, would be equal to 3,500 feet. 3,500 feet reduced from an angle of 40° to 10° gives 2,850 feet. Then 2,850 feet, added to 6,250 feet, or A,C, would be equal to 9,100 feet, or P,Q, the entire depth of the coal measures down to the carboniferous limestone in the centre of the trough Penllergaer. P,Q, or 9,100 feet carried out to an angle of 35° would give 11,000 feet, equal to P,R, and equivalent to the total thickness of the coal measures down to the carboniferous limestone on the south rise Penllergaer; thus placing the upper tilestone of the Llynvi district about on a level with Hughes's vein of coal on the south rise in the neighbourhood of Swansea or Penllergaer. This would make Hughes's vein the same as the middle Bettws in the Llynvi valley to the east, and that of the Mynyddyslwyn bed in the north trough, Mon-

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and S,N, &c. are perpendicular. For example, The line P,R, is perpendicular to the plane of the strata dipping north from the south outcrop at an angle of 35°, and P,Q, perpendicular to the same in the centre of the trough.

mouthshire. Or, as the difference between the hypothenuse of a right-angled triangle at an angle of 40° and 10°, added to the same of 40° and 10°, the inclination of the strata on the south rise of the south trough, and the same on the south rise of the north trough in the Llynvi district, and the dip of the strata on the north basseting edge of the north trough in the Baglan district to the west, and the same in the Llynvi locality, so has been the extent of the subsidences between Llynvi (north trough) and Penllergaer, 1,750 feet of which has been caused by the increase in the angle of dip of the measures from the apex of the central anticlinal in the vicinity of Baglan, over the same in the Llynvi, produced by the central axis and north lateral pressure jointly; and 1,750 feet by the difference in the angle of dip on the south rise of the south trough, and that of the same on the south rise of the north trough in the locality of Llynvi, caused by the joint influence of the central anticlinal and south lateral pressure, commencing near Aberavon, from whence transverse or anticlinal faults rapidly followed each other in a westerly direction, until the longitudinal fault traversing the south trough became spent, and the strata on the north side of it (by allowing for relative position, to the central anticlinal), were brought down on a level with the same, to the south. This appears to have been nearly opposite the Town of Swansea, and amounting in the aggregate to the 1,750 feet.

It will be seen by reference to No. 6 Diagram, that the anticlinal faults or subsidences have been represented in one. In a sketch so small, they would be scarcely intelligible shewn separately.

PROOF.—The upper tilestone which is immediately under the middle Bettws vein of coal in the south trough Llynvi, may be seen to shave, as it were, the summit of Llangeinor Mountain in the main trough to the north, at an elevation of about 1,600 feet above the level of the sea. Hughes's vein of coal (a detached continuation of the middle Bettws vein) on the south rise to the south of Penllergaer, is about 3,000 feet in descending order in the measures beneath the highest stratum. That vein would be, therefore, in compliance with the angular theory, by allowing the surface in the centre of the trough to the north to be 500 feet above the level of the sea in that line of section, about 2,400 feet beneath the same, or 1,900 feet under the level of the sea. Then 1,900 feet, the depth of Hughes's vein of coal in the centre of the trough Penllergaer, beneath the level of the sea, added to 1,600 feet, about the height of the upper tilestone above the same in the north trough Llynvi district, gives 3,500 feet, which corresponds with the extent of subsidences between Llynvi and Penllergaer. This the reader will understand to be merely an approximation, and not in strict accordance with the exact elevations and the angles of inclination presented by the strata. A more minute and strictly accordant demonstration would necessarily involve a series of additional diagrams and sections which would render the work too expensive for those for whom it is chiefly intended. It is, however, sufficiently near for our present purpose, as also to shew the importance of the theory; indeed, the advances we have already made in the matter, by adhering to the minutest particulars in elevations, &c., enable us, in addition, to state that the extent of every fault, large or small, in the Coal Field of South Wales, or that of any other, can be clearly and satisfactorily determined.

It is quite manifest, from the circumstance of the change of dip in the measures from the apex of the central anticlinal for the north trough, giving an increase at Baglan of about 30° over that of the same in the Llynvi; that the local or trough faults must have ensued in the intervening space, thus, in compliance with the angular theory, producing an increase in the same strata on the south rise of the north trough, proportionate to the increase in the angle of dip, and equal in the deposits under consideration (from the upper tilestone down to the carboniferous limestone) to 1,750 feet, but owing to longitudinal faults which have occurred, ranging from the Ton Mawr trough fault, —the first we meet with of any particular moment in a westerly direction from the Llynvi district,—towards Neath, between the centre of the north trough and the apex of the central anticlinal in this part of the Field; this addition has taken place on the south rise only, or to the south of the longitudinal faults, and the strata in the centre at Forchdwm and Cefn Morfydd hill near Neath, have been affected but to an extent equal to about 1,100 feet, caused by the local transverse fault, passing from the south rise of the north trough, through Ton Mawr on to Melin Court in the Vale of Neath, and is such as is represented in the diagram a local or trough fault.

There are numerous minor dislocations between Llynvi and Tonmawr, but as they do not produce any important alteration in the position of the measures, it would be scarcely necessary in this place to enter into further particulars respecting them; it will suffice to state, that what one heaves up the next casts down.

We shall, in the next place, proceed to account for the

remaining 1,750 feet, as well as the 650 feet which have been left in Cefn Morfydd Hill, &c., north trough, by the intervention of the longitudinal faults to the south, making together between Cefn Morfydd by Neath and Pellergaer, 2,400 feet; but it must be remembered, only 1,750 feet between the Baglan district to the south of Neath and to the south of the longitudinal faults, and the latter place.

The succeeding subsidence we come to in a westerly direction, is an extensive down-throw west. This ranges from the foot of the south rise of the measures in the south Basin or trough (we should perhaps mention from the longitudinal fault traversing the south trough) by Aberavon, crossing the central anticlinal between the Cwm Avon Works and Swansea Bay, hence to the back of Baglan House, the residence of Howell Gwyn, Esq., M.P., and terminating in the north trough, Vale of Neath, a little north of that town, and is such as represented in the diagram an anticlinal dislocation, the first of which occurs between Llynvi and Penllergaer, and which divides, as previously observed, the entire mass in a transverse or meridional direction throughout its extent.

If, then, the Vale of Neath is traversed by a dislocation producing a north-west subsidence of the measures, of which there is a strong evidence to justify (if not from the summit to the sea, certainly from Aberpergwm to near the town of Neath), the probability is, that it amalgamates with the first anticlinal fault where the latter enters the valley: but from the immense collection of alluvial deposits at the point of assumed junction of these dislocations, this cannot be determined by ocular demonstration;

nevertheless, as the measures on the north-west side of the valley appear to be somewhat lower than the same on the other, we have strong reasons in support of the consideration, of the Vale of Neath being ranged by a dislocation or fault, uniting with the first anticlinal where the latter enters the valley.

Close to the west end of the town of Neath there is another anticlinal fault, a down-throw west of some magnitude. This, also, takes its rise near Aberavon and runs nearly parallel to the former. This is again followed by a second, passing by the Neath Abbey Works; but these two are in a great degree counteracted by an up-throw west between the latter place and Drumma Mountain. We must, consequently, view them in the aggregate, as producing no material difference in the position of the strata at Neath and Drumma, so that the measures at Drumma may be regarded on a level, or nearly so, with the same at Neath to the east of the second anticlinal fault, and in the intervening space considerably beneath.

A little to the north of the central anticlinal where this up-throw west passing to the north along the east side of Drumma Mountain takes its rise, a longitudinal dislocation, or up-throw north has ensued, taking a direction from near Briton Ferry, north of Red Jacket towards Swansea, and is probably an intercepted extension of that to be seen north of Cline Wood, west of Swansea. The strata immediately in contact with this fault, present a greater inclination on the south than on the north side of it, thus accounting for the measures in Drumma Mountain, being on a higher level than the same to the east of the transverse up-throw west bounding it. This transverse

fault flanking Drumma Mountain on the east, from its commencing within the precincts of the north trough, comes under the denomination of a trough fault, or local transverse as represented in the diagram. It is in fact, the same in principle as the Ton Mawr previously noticed, but reverse in effect, inasmuch as instead of being a down-throw west, it is an up-throw in that direction. This is important, as it appears to demonstrate, that if it had not been for the intervention of the longitudinal dislocation extending in a westerly direction from near Briton Ferry, and ranging parallel to the central anticlinal, the strata in Drumma Mountain would have been on a level with the same to the east, between that and the first anticlinal fault to the east of the town of Neath.

In going west from Drumma Mountain several large faults are met with, the most extensive of which appear to be anticlinals producing west subsidences, and the last of which, runs north from the point in Swansea Bay where the south lateral pressure brings its first or last influence to bear on the coal measures. These together, (including the first anticlinal fault immediately to the east of the town of Neath, which brought down the 650 feet left in Cefn Morfydd Hill, by the interruption of the longitudinal dislocations between that and the apex of the central anticlinal to the south,) would be equal to 2,400 feet: this added to 1,100 feet, the extent of the Ton Mawr fault, would be equivalent to 3,500 feet, the extent of the subsidences between Llynvi and Penllergaer.

Although we have made use of this explanation relative to the subsidences between Llynvi and Penllergaer, yet, as there appears to be some uncertainty remaining with

regard to the extent of the Ton Mawr fault, and the first anticlinal to the east of Neath, we consequently purpose going through three distinct expositions, either of which corresponds with the 3,500 feet between the two extreme points, but presenting some little disparity in the intermediate space; indeed, the very complicated nature of the strata between Llynvi and Drumma Mountain, which seems to have hitherto baffled the most experienced and accomplished in arriving at a clear and satisfactory classification of them, necessarily demands that we should extend our observations on this subject. Such will, moreover, better enable our readers to judge how far we may be considered justified in stating, that the Llynvi tilestones take up a position immediately under Hughes's vein of coal in the Swansea district.

EXPLANATION FIRST.

The distance from the upper tilestones down to the cock-shot rock on the anticlinal rise in Llynvi district, is under 2,300 feet, the angle of inclination about 10°. In proceeding westward from the latter place, the first fault we meet with of any importance, (although there are many small ones intervening which on the whole produce little or no variation in the position of the measures,) is the Ton Mawr, extending, as before observed, from the foot of the south rise of the north trough through Ton Mawr on to Melin Court in the Vale of Neath to the north, where it amalgamates, or merges into the north-west subsidence traversing that valley, and is such as represented in the diagram, a local or trough fault.

It is estimated to be a down-throw west of from 100 to

200 fathoms, but, in this exposition, we shall consider it about 100, or 600 feet. This made room, therefore, for that extent of additional deposits at Forchdwm and Cefn Morfydd Hill to the west, which, added to 2,900 feet, the increase of 30°, (the increase in the thickness of the measures between the cockshot and the tilestone, on the anticlinal rise to the west of the Ton Mawr fault, making the additional 600 feet, over the same in the Llynvi district to the east,) would give 3,500 feet,—a separate or distinct deposit of 600 feet, and an expansion in the thickness of the same strata, of 600 feet.

This accounts for only 600 feet of additional deposits out of 1,750 feet, on the anticlinal rise between Llynvi and Baglan, and east of the first anticlinal fault by Neath, we have, therefore, 1,150 feet, to make up the total subsidences, as herein considered, in compliance with the increase of the entire measures, (that is, from the tilestone down to the carboniferous limestone,) in proportion to the increase in the angle of dip between those places. This remaining 1,150 feet must be attributed to longitudinal faults producing south subsidences between the centre of the north trough and the apex of the central anticlinal, without effecting much, if any, alteration in the same in the centre at Forchdwm and Cefn Morfydd Hill. These have not only given to the anticlinal rise the additional 1,150 feet increase in the entire measures, but have, moreover, produced in this district a space equivalent to a repetition of the outcrops of the same strata. Then, in making a section of the coal measures from the cockshot on the anticlinal rise, (locality of Cwmavon, east of the first anticlinal fault,) to the crown of the south profile of Cefn Morfydd Hill, we have not merely the 600 feet increase in

the thickness of the measures, as compared with Llynvi, and arising out of the increase in the angle of dip, but have also about 1,150 feet caused by a repetition or a space equivalent to a repetition of the outcrops of the strata, making, together with the 2,300 feet, about the thickness from the tilestone down to the cockshot in the locality of Llynvi, 4,050 feet, to which we must again add the thickness of the measures above the kitcote tilestone in Cefn Morfydd, say 600 feet, giving a total of about 4,650 feet; yet the depth from the top of Cefn Morfydd Hill, in the centre of the trough, down to the cockshot is under 2,900 feet, which is 1,750 feet less than a section as just stated, without allowing for a space equivalent to a repetition of the outcrops of the same strata, and from the kitcote tilestone, which may be considered the same as the Llynvi, under 2,300 feet, or about the same depth as in the centre of the north trough, Llynvi. On the contrary, and constructing the section on the anticlinal rise without adhering to any allowances beyond that of the increase in the angle of dip, it would give about 4,000 feet (that is, from the Cefn Morfydd tilestone down to the cockshot rock); thus, making the bed of coal next above the kitcote tilestone in Cefn Morfydd, the same as the six-foot bed in the Penllergaer series, Swansea, which is about 1,000 feet in the measures above Hughes's vein of coal and the kitcote tilestone, a separate or distinct deposit from that of the Llynvi tilestone, and 1,000 feet in geological position on an angle of dip of 35° above the same.

The next important transverse fault we arrive at in a westerly direction from the Ton Mawr, is the one previously distinguished as the first of the anticlinals, commencing at the longitudinal fault traversing the south

trough by Aberavon, passing through the Gnoll Castle grounds a little east of the town of Neath, and terminating in or uniting with the north-west subsidence ranging the Vale of Neath near Llantwit church.

This fault on the apex of the central anticlinal is a down-throw west of something under 500 feet; but on approaching the centre of the trough by Neath it increases materially, and ought to be in compliance with this exposition 1,650 feet. This, therefore, brought down the kitcote tilestone of Cefn Morfydd about 1,650 feet in the centre of the trough, and only affected the strata on the back of the anticlinal to the south, to an extent of something less than 500 feet. The kitcote tilestone would, consequently, be 1,650 feet in the centre of the trough beneath the same in Cefn Morfydd Hill, to the east of this subsidence. This, together with the north-west subsidence ranging through the Vale of Neath, and with which it unites a little above Neath, forced the north outcrop of the coal measures to the north-west of the Vale of Neath, some distance north of the same to the south-east of the Vale.

The remainder of the subsidences which have ensued between Neath and Penllergaer, and to which we have adverted in the preceding pages, were produced in the same manner as that close to the east side of the Town of Neath, (first anticlinal fault,) and which amount in the aggregate to about 1,300 feet. The up-throw west, ranging parallel with Drumma Mountain, counteracts the two down-casts west, between that place and Neath; we should, therefore, view the 1,300 feet as having taken place to the west of Drumma. This, added to the 1,650 feet, the extent of the

first anticlinal subsidence in the centre of the trough, and the 600 feet produced by the Ton Mawr fault, would give 3,500 feet, the extent of the subsidences between Llynvi and Penllergaer.*

In concluding this explanation it would, perhaps, be advisable to remark, that (in compliance with the views advanced) we have, in addition to the increase in the thickness of the same strata, proportionable to the increase in the angle of dip between Llynvi and Baglan, a space produced by longitudinal dislocations between the centre of the trough and the apex of the anticlinal to the south about the same extent, whereas, in the centre and to the east of the first anticlinal, the increase of strata over Llynvi is not more than about 600 feet.

Before entering into the merits of the second view of the position taken by the measures, and the extent of the subsidences in the district under notice, it is essential to point out that the central anticlinal at Baglan, from its

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* If, however, we admit the kitcote tilestone, Cefn Morfydd Hill, to be a distinct deposit from that of the Llynvi, and the Ton Mawr fault to be a down-throw west of 1,750 feet, and that no longitudinal faults have ensued on the anticlinal rise between Cefn Morfydd and the apex of the central anticlinal, the first anticlinal fault by Neath would be reduced to about the same extent as on the apex of the anticlinal, something under 500 feet. This would unquestionably prove the vein of coal immediately above the kitcote, Cefn Morfydd Hill, to be the same as the six-foot in the Penllergaer series, and it would also agree with the classification advanced by Sir Henry De la Beche, of the measures to the west of the Ton Mawr fault, but would produce some difference to the east of the same, without the aid of changes which would be viewed, perhaps, by some as improbable.

being south of the whole of the Pennant and Upper Mynyddyslwyn or Penllergaer series, acted upon them there, and to the west, in the trough to the north, as a south lateral pressure.

As this elevating force (if such we may term it) passed to the east, it gradually worked its way under the whole of the measures in the Coal Field, separating the whole of the upper or Penllergaer, and some of the Pennant series along its apex; and on reaching a point north of the transverse centre of the upper series in its eastern course, caused them, with the assistance derived from the gravity of the mass inclining southward, to turn over into the south trough; so that on passing east of Braich y Cymmer in the Garw Valley, it became a north lateral pressure on these measures, being directly opposite to the position it presented at Baglan and to the west. This it maintained to the River Taff, where it crossed over to the south again, and presented a similar barrier or protection to the measures in the north trough at that end of the Coal Field (east of the River Taff) as at Baglan and to the west.

Here then we have the same elevating force reversing the order of its pressure on a large proportion of the coal measures within a distance of a few miles, and effecting a change so great, in conjunction with other powers co-operating with it, as to reduce the thickness of the upper or Penllergaer series, which is at that place about 3,000 feet with twenty-six beds of coal, down to less than 200 feet with only two beds (Llynvi Valley). This, with the fact of there being a greater thickness of measures, with five seams of coal in the north trough, Monmouthshire, to the east, clearly demonstrates that entire beds of coal, clay,

shale, &c., have been devastated from above, when abrading and triturating influences quickly milled them up into small fragments which were afterwards transported by the agency of water, into the neighbouring sea, or some distant situation, and leaving but the pebbled boulders which are now extensively distributed over the surface covering the coal strata, as the only existing type of the wreck behind to tell the tale.

We would moreover remark, that the central anticlinal and the north lateral pressure acted on a large proportion of the measures in the north trough, Baglan district, in the same manner as the south lateral pressure and central anticlinal have done on the same in the south basin in the Llynvi locality. To the west of Swansea, the central axis possessed precisely the same bearings on the entire coal measures in the north trough, as the south pressure on the same in the south trough to the east of Swansea Bay.

### EXPLANATION SECOND.

In this exposition of the subsidences, and the position taken by the strata, we shall consider the Ton Mawr fault to be a down-throw west of 1,150 feet, which is nearly 200 fathoms; so that we have 600 feet wanting to make up the 1,750 feet (the extent of the subsidences), giving rise to an increase in the angle of dip of 40° to the west of the Ton Mawr fault, over that in the Llynvi district to the east, and which must be attributed to longitudinal faults intervening Cefn Morfydd Hill and the apex of the central anticlinal.

The distance from the tilestone down to the cockshot on

the anticlinal rise, Llynvi, is, as before stated, under 2,300 feet. This added to 600 feet, (the expansion in the thickness of the same measures produced by an increase in the angle of dip,) would give 2,900 feet, to which we must again add 600 feet, (the extent of the longitudinal faults between Cefn Morfydd Hill and the Saddle Back to the south,) making together 3,500 feet. A section, therefore, from the kitcote tilestone, Cefn Morfydd Hill, down to the cockshot on the central anticlinal, in compliance with this view, would give 3,500 feet, and in the centre of the trough to the east of the first anticlinal fault by Neath, about 2,300 feet, or about the same distance as in the locality of Llynvi. This would reduce the first anticlinal fault in the centre of the trough by Neath, down to 1,100 feet. Then as the upthrow west, east of Drumma Mountain, counteracts in a great degree the two intervening anticlinals between that and Neath, we may consider the remaining 1,150 feet of subsidences to have ensued west of Drumma, thus, bringing down the Llynvi tilestone (north trough Llynvi) on a level, or nearly so, with Hughes's vein of coal near Swansea, or south rise Penllergaer.

The striking similitude between the kitcote tilestone. Cefn Morfydd Hill, and the Llynvi, and our not being able to discover any bed of rock near the six-foot Penllergaer series to bear any consistent resemblance to it, favour this view considerably; more especially, when we find in going eastward from Cefn Morfydd even to Monmouthshire, the most perfect identity in it wherever it takes ground; and moreover, this corresponds in every particular with the proof advanced in a former page: but as we, however, find the rocks in this coal field in many instances, to become so changed as to obliterate entirely

their identifying qualities in a distance of a few miles, the importance which would have been otherwise attached to its unchangeable nature or appearance becomes materially weakened. The point at issue between these two expositions appears to be, therefore, whether the kitcote tilestone is the same as the Llynvi, or a separate rock, and geologically the same in position as a bed near the six-foot in the Penllergaer, and 1,000 feet in the measures above the Llynvi tilestone. If the same as the Llynvi tilestone, the latter view is unquestionably correct, unless it may be deemed probable that the distance between the Llynvi tilestone and the cockshot has increased to nearly as much again in a distance of a few miles, a very unlikely supposition in measures so uniform and regular as those in this part of the coal field. If the former, it involves another and a third consideration, as we could not consistently with the theory herein advanced consider the Ton Mawr fault to be no more than 600 feet, and at the same time admit the kitcote to be a distinct bed from that of the Llynvi tilestone and 1,000 feet in the measures above it, and to correspond in position with a rock near the six-foot in the Penllergaer series.

### CHARACTERISTIC FEATURES OF THE TILESTONE ROCK.

The characteristic features which enable us to distinguish the tilestone from the surrounding rocks, are that it splits in thin layers of from half an inch to one inch in thickness, for a depth varying from ten to twenty feet. The Pennant immediately under this raises in their beds, but considerably thicker and of a coarser granulation; moreover, the lamination of the Pennant do not

present that even and delicate surface so peculiar to the tilestone, in which may be frequently observed exceedingly fair impressions of small plants, the branches of which are exquisitely delineated, and so perfect that it is only in the shale we find any to bear comparison with them.

### EXPLANATION THIRD.

We have now come to the third and last explanation of the subsidences and the position taken by the strata between Llynvi and Penllergaer; and, although some of the reasons which we shall have occasion to advance, may perhaps appear in one respect conjectural as compared with those considered in the former explanations, yet, we believe that they will be found to a certain degree compatible with features which in some measure warrant the conclusion, and by admitting this, *in its fullest sense*, it would correspond pretty nearly with the classification advanced in the memoirs of the Geological Survey of Great Britain, vol. 1, "Formation of rocks, &c., in South Wales," wherein it is stated, that high beds above the six-foot vein of coal in the upper or Penllergaer series which is about 1,000 feet above Hughes's vein, are to be met with in Drumma Mountain, March Howell, and Cefn Morfydd Hill. On the south and to the east, the upper series appears to have rolled over into the south trough Llynvi valley, and in the Taff section the Maes Mawr vein of coal may represent the bottom of the upper series; so that according to this view we are to consider the Maes Mawr coal,* (Taff valley,) the same as Hughes's vein of coal, Swansea.

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* At the meeting of the British Association, held at Swansea in August last, Mr. Struve stated that Hughes's vein of coal, Swansea,

Should it be deemed inadmissible for the thickness of the strata, from the upper tilestone down to the cockshot, to have increased nearly as much again between the Llynvi district and Cefn Morfydd, we can scarcely reconcile the consideration of the kitcote tilestone, Cefn Morfydd, being the same as the Llynvi, and also equivalent to a bed above the six-foot in the Penllergaer series near Swansea, (which is there about 1,000 feet in the measures above Hughes's vein of coal,) without the aid of changes which may in some degree be considered improbable, but in this instance very possible; i.e. that the high elevation into which the upper series, and some of the Pennant measures have been uplifted by the central anticlinal in the Llynvi district, which, there, as before observed, passed immediately under, and reached a point somewhat north of the transverse centre of the upper series, and which, to the west, acted upon those measures laterally, turning over the whole of the upper series, and separating some of the highest beds of the Pennant, the basseting edges of which were consequently exposed to the action of air and water, which together, quickly found their way through the fractures inevitably attending such separations, and destroying the adhesiveness which held the different strata together, the harder or more compact beds of which, from their inclined

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was the same as the Dehewyd beds. This in some measure corroborates or corresponds with the view advanced in the first edition of this work, following under the head of Red Ash or upper series, and runs as follows:—There is a working on the lowest bed of coal in the upper series in the parish of Llantwit-vardre, on the road side leading from Llantrissant to Tre Forrest. This road runs through Dehewyd. But, as the term beds is indefinite, Mr. Struve, might have probably meant the Maes Mawr coal, in that case there would be some difference.

position and gravity, subsided into the south trough to the south, where they covered beds considerably beneath their proper position in the measures, and leaving the softer positions of the stratification, (equivalent to beds between the six-foot, and a bed of rock near Hughes's vein of coal in the Penllergaer or upper series, mostly arenaceous, and argillaceous shale, with under clay interstratified,) very much broken. These, by disintegration and abraiding influences, were soon reduced into small fragments, and afterwards transported by impetuous rapids, or forced by lateral pressures into the adjoining sea or some remote part.

Malte Brun, in speaking of mountain slides, page 435 Physical Geography, thus relates an extraordinary catastrophe of this kind which took place in France: "Some years ago, the commencement of an event of this kind was observed at Solutie, near Magon. After some great rains, the strata of earth which lay upon the mountain of Solutie, slid along over couches of calcareous stones which constitute the body of the mountain. They had already advanced several hundred yards, and the village was about to be buried in ruins, when the rain ceased, and this moving mass of earth was arrested in its progress." A still more astonishing fact of this kind is related: A part of the mountain Goima, in the Venetian states, detached itself during the night, and glided along, with several houses, which were carried into the neighbouring valley: in the morning the inhabitants who had felt nothing, were extremely astonished when they awoke to see themselves at the bottom of a valley, and for a long time imagined that a supernatural power had transported them through the air into some distant climate, until upon examining the

environs, they perceived the traces of the revolution which had so wonderfully spared them. The view we have advanced, relative to the lateral subsidences of the harder or more compact beds into the south trough to the south in the Llynvi district, is strongly supported by manifest features at Garth Hill near Maesteg, and Moilgele Mountain, where this avalanche is assumed to have occurred. The south escarpments of those hills fall into the south trough at nearly the same angle of inclination as the strata of which they are constituted; and, in both instances, the surface stratum is rock, thinly clad with soil: that of Garth hill, being the rock immediately overlying the rider vein of coal next above the upper black band, and that of Moilgele a rock somewhat higher in the measures. Indeed, this locality requires only a cursory examination to substantiate in a great degree, the tenable grounds upon which this explanation is based. Garth Hill is insulated and separated from Mynydd Tir y Cerrig to the north, by a deep ravine, through which ranges the central anticlinal, passing onwards from hence in its easterly course to the north of Moilgele Mountain. Parallel to the anticlinal, and traversing the south trough through a part of the Llynvi valley to the south of those hills, is an extensive down throw south (a continuation of the longitudinal fault in the south trough extending from Aberavon on the west, to the Sirhowy valley in Monmouthshire, on the east); we can, consequently, readily conceive when the central anticlinal uplifted the strata along its apex into a reverse order of inclination, and effecting the fault just mentioned, or out of their original horizontal position into a saddle back, from whence the measures incline north and south, thereby exposing the basseting edges of the strata separated, to the combined influence of air and water, which

owing to their shattered or dislocated condition arising from the uplifting force being opposed to a laxity of pressure from above, soon destroyed their adhering qualities, that even their own weight, favored by an inclination of about 15°, would necessarily cause them to descend into the south trough, in the Llynvi valley to the south. Indeed, in one or two cases, we have traced the direction of what appeared to be lateral subsidences for a considerable distance down the mountain slopes in the Llynvi district, being guided by what seemed to be fragmentary remains of beds of coal, clay, shale, &c., evidently presenting the appearance of having been left behind in the tract of descent.

There may be those, perhaps, disposed to consider this view somewhat speculative; it is, nevertheless, quite certain that many of the softer beds of fire clay, &c., in the coal measures, particularly in the upper division of the mass, become so tenacious, and *puck* so exceedingly on any part of them being exposed to aqueous and atmospheric action, as entirely to destroy their adhesive properties, over large areas. Then, under the conditions advanced in this exposition, the rocky or compact beds would, by their own gravity on a slight inclination, necessarily descend over the surface of the fire clay until intercepted in their progress by some effectual barrier, precisely on the same principle as a sliding avalanche descends over the mountain slopes into the valleys beneath.

By admitting this hypothesis, the increase in the thickness of the strata from the tilestone down to the cockshot rock could be easily and satisfactorily accounted for, as such would prove the measures above the six-foot in

the Penllergaer series to be the same as those above the kitcote tilestone, Cefn Morfydd by Neath, and also the kitcote tilestone to be a continuation of that worked by Lord Dunraven in the vicinity of Bettws, Llynvi Valley, which may be traced from thence at intervals to the River Taff, where it once more passes over into the north trough, in which it continues to the eastern boundary of the coal-field, its extreme outcrop appearing at Penrhiw Frank near the British iron works, Monmouthshire; but instead of its occupying a position in the measures near Hughes's vein of coal, Swansea, it would, in compliance with these considerations, be about 1,000 feet above.

There are, however, inconsistencies connected with this explanation which render it rather doubtful, in the absence of more conclusive evidence, to be adopted; that is, the distance from the upper tilestone on the anticlinal rise in the locality of Llynvi, corresponds pretty nearly with the same on the north rise of the north trough, Monmouthshire. We have, therefore, no reason to suspect any intervening beds to be absent; and moreover, the fact of the north outcrop to the east of the Neath Valley being considerably south of the same east and west of those places, argues strongly that a lateral subsidence of the upper series in the manner just described, leaving behind it (out of the wreck) the upper tilestone with two seams of coal and their intervening strata in the south trough of this district, did not ensue; but a southerly movement *en masse* must have occurred, and the fragmentary traces of a supposed lateral subsidence down the mountain slopes, might have arisen out of the fault running parallel to the central anticlinal, or attributable to the remains of beds above, which have passed away.

We may also add, the almost inevitable certainty of such a slide being attended with overlaps, and great inconsistency in the superimposing order of the beds in the south trough, whereas the reverse is the case, and with one exception (that is in the Dehewyd district, where the upper tilestone appears to have slid from off the measures to the north, and to have taken up a position relatively in an ascending section on the south outcrop, considerably beneath the same to the west in the Ogmore district, and also as compared with a section on the anticlinal rise north of Dehewyd, and in the direction opposite to that of the supposed avalanche) they are found to present that uniformity of position reconcileable only with a primeval order of deposition. Notwithstanding, it is quite obvious, that the strata above the tilestone were, from the direction taken by the central anticlinal in the Llynvi district effecting the southerly movement of the entire mass, so shattered and disrupted as to render them of easy transport to powerful torrents, &c.; but the tile-stone and the accompanying beds, that is where they are absent, now occupying a position in the south trough, were devastated only to the north of the south down-throw fault ranging parallel to the central anticlinal, particularly in the vicinity and immediately east of Maesteg, and, like the measures above, afterwards swept away into the adjoining sea, or some distant situation.

It would be incompatible, after what has been stated in this exposition for and against, to recognise this view with a degree of strict assurance, however much we may be disposed to give it the preference, more especially as the distance from the tilestone on the north rise, south Basin Llynvi, corresponds pretty nearly with the same in the

north trough, Monmouthshire, some twenty miles to the east. The question which therefore remains to be determined is, whether the kitcote tilestone is equivalent in position to a bed near the six-foot in the upper series, and a distinct deposit to that of the Llynvi tilestone, or one and the same. We are, at present, disposed to consider the kitcote (Cefn Morfydd Hill), to be a continuation of the Llynvi tilestone, and (unless credit is given to the avalanche in its fullest sense as explained in this exposition,) to have no connection whatever with any bed near the six-foot seam of coal (Swansea), and that Cefn Morfydd Hill, &c. are insulated or surrounded by dislocations which have not only rendered a classification of the strata therein a matter of considerable difficulty, but have also so changed the structural features of the strata, as to form in some measure a dependent anticlinal. The longitudinal faults between Cefn Morfydd Hill and the apex of the central anticlinal, extending from the Ton Mawr dislocation to the first anticlinal fault immediately east of the town of Neath, have so acted on the measures as to effect a space, equivalent to a second outcrop as it were of the same strata, presenting the deceptive appearance of being the outcrops of distinct deposits; that is, the kitcote tilestone (Cefn Morfydd Hill) has suffered a down-throw south, so that the outcrop on the anticlinal rise to the south is considerably south of the point where it would have appeared outcropping unaffected by the longitudinal dislocation, and equal to an extent of about 600 feet. This, added as before stated to 1,150 feet, the magnitude of the Ton Mawr fault, gives 1,750 feet, being equal to the increase in the thickness of the same strata, caused by the increase in the angle of dip on the anticlinal rise, west of the Ton Mawr fault. The first anticlinal imme-

diately east of the town of Neath, and which forms a junction (as before observed in the second explanation) by Llantwit in the Vale of Neath with the north-west subsidence ranging that valley, cast the kitcote tilestone down west in the centre of the trough about 1,100 feet, and has only affected the measures on the anticlinal rise to the south to the extent of 500 feet, thereby annihilating the longitudinal dislocations to the east. In its westerly course from Neath it crosses two anticlinal faults throwing the strata down west, between that and the up-throw west ranging parallel to Drumma Mountain; in which mountain the strata, from the occurrence of a longitudinal dislocation to the south, present that anomaly of position* as observed at Cefn Morfydd, a dependent or local anticlinal. After several more anticlinal faults heaving the strata down west, between the up-throw west, Drumma, and Penllergaer, the tilestone takes up a position in the measures or outcrops south of the latter place nearly on a level with Hughes's vein, a well-known bed of coal on the south rise, Swansea district.

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* These anomalous features—local anticlinals—are common to this part of the coal field. One extends from Pontardawe in the direction of Penllergaer. Their local positions, flanked as they seem to be in every instance by extensive local and anticlinal dislocations, afford a clear solution of their productions. The sudden termination of an anticlinal fault by the interception of another perpendicular to it, would inevitably (under the intense pressure to which the coal measures were subjected at the formation of the central anticlinal and north lateral pressure, but in this part of the coal field, north and south lateral pressure,) give rise to one of these irregular anticlinals which would be entirely annihilated by the next anticlinal dislocation.

The adoption of either of the explanations herein advanced, relative to the faults and the position of the measures would not in the least invalidate the principle promulgated, of the increase in the thickness of the strata being in the same proportion as the increase in the angle of dip, nor yet of that relative to the subsidences. Then, the advantages which must accrue from a theory so simple, cannot, we think, fail to impress the most dubious with its importance, placing, as it does, within the power of the geologist and surveyor, a rule by which the extent of the faults, large or small, which have ensued in this valuable and extensive field of mineral wealth, or that of any other, can be easily and correctly determined, as well as other advantages, and which appears to be, as Mr. Phillips beautifully remarks, on the merits or literal sense of the word theory, " like the unchangeable summit of a cone whose base continually enlarges to include every known fact appertaining to the subject, and whose every part is linked in harmony, according to one simple and intelligible principle."

Whether by admitting the tilestone of Cefn Morfydd Hill to be immediately under Hughes's vein of coal, (Swansea,) and the same as the Llynvi, or equivalent and corresponding with a stratum above or near the six-foot in the Penllergaer series at the same place, we are inevitably forced to the conclusion from what has been advanced in the preceding pages, that the coal measures from the Sirhowy Valley in Monmouthshire on the east, and beyond Llanelly in Carmarthenshire on the west, were, prior to their subjection to the influence of the anticlinal forces, about the same thickness, and the beds of coal similar in quality; and that the subsequent movements of these pow-

erful agents produced the changes which have ensued in them, i. e., the elevated position into which the measures have been uplifted by the central anticlinal, which there became more central in the Coal Field than to the west, the alteration in the quality of the coal, and the different angles of inclination to be observed in them.

The central direction taken by the central anticlinal through the Coal Field in the district between the head of the Llynvi Valley and the River Taff, (whereas east and west of those places it passed south, thereby affording a protection as a south lateral pressure to the coal strata,) caused the coal measures with the north lateral pressure, favored by the gravity of the entire mass inclining in that direction to move *en masse* to the south, its maximum of pressure being directed diagonally to a square or nearly so between the central anticlinal and south lateral pressure, now the foot of the south rise of the measures in the south trough, whilst a nearly horizontal lateral force passed above the diagonal weight, and chiefly derived from the north lateral pressure, at the same time disrupted and devastated the whole of the upper or Penllergaer series, produced a scene in the wreck of matter much easier to be imagined than depicted. Hence it is, that the north outcrop of this district is considerably south of the same east and west of it. This clearly shews, with what has been explained relative to the faults, that it is the direction taken by these anticlinal levers, through any series of stratification, that determines their subsequent position, and consequently, in many instances a mass may have been separated and forced miles away from its original position, the extent of removal being regulated by the direction and intensity of the forces. This leads us to the subject of de-

nudation, and as our views on that subject differ somewhat, in connection with the angular theory, from those of geologists who have paid considerable attention to the matter, we shall, in the next place, offer a few observations under that head.

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## DENUDATION OF THE COAL MEASURES IN THE SOUTH WELSH COAL FIELD.

It is, we believe, considered by some of our most eminent geologists, that the coal fields mantling round North and South Wales, were at one period joined together, and that the patches of coal measures which are now distributed here and there, are merely out-liers of one great whole, and that the subsequent operations of the anticlinal forces have disrupted and laid waste the once-intervening coal strata, which were afterwards swept away by denudation.

If we comprehend rightly, it is supposed that these out-liers occupy the same local position as prior to the convulsion in nature which disrupted and devastated the coal strata between, and that the only alteration which has ensued in them, is extensive faults and change of position in the angle of inclination, with some of the upper portions of the strata destroyed. By laying down on a plan the surface dip of the strata in two or more of these out-liers, as the case may be, and joining them together by what Geologists designate normal curves, the extent of matter removed from between is ascertained; that is, imaginary lines carried out from one out-lier to another according to the inclination presented by the strata rising to the surface,

so that if the angle of dip presented by the strata in either case be the same, and the beds nearly on the same level, these normal lines would meet in the form of a dome within a short distance of the centre point between the out-lying portions; and when the angle of dip in the strata is considerably greater on one of those out-liers than on that of the other, the point of meeting of these normal curves or lines would show a corresponding disparity, the variation from the centre-point being in the same proportion as the difference in the angle of dip. The best occular demonstration of this in the South Welsh Coal Field is to be observed about a mile or a little more to the east of the Maesteg works. There, may be seen, the cockshot rock rising north and south to the apex of the central anticlinal, and forming what is termed by miners a saddle-back within a few feet of the centre of the surface trough, between Garth Hill on the south and Mynydd Tir y Cerrig on the north. The Pennant measures are to be observed basseting out in opposite directions on each side of it, those of Garth outcropping north in regular succession one after another up the north side of that hill, at an angle of about $15^{0}$ or less, and those of Tir y Cerrig presenting a south outcrop up the south escarpment of that mountain, at nearly the same angle of inclination.

An examination of this district would apparently dispel the difficulty of at once comprehending that normal lines on a plan or section extending across the surface trough intervening those hills, in compliance with the inclination of the strata, would enable us to arrive at a computation of the mass which was upheaved and broken by the anticlinal lever, and afterwards removed from between by denudation. In conformity with this view,

geologists consider that the coal fields mantling North and South Wales are merely out-liers of one whole, and the masses of matter which once filled up the void or made up the continuity of the beds between have been subsequently removed, and that it is more than probable that out-lying portions of the South Welsh Coal Field occupy tracts covered over by the waters of the Bristol Channel. We must now draw attention to the consideration of there being evident features in the immediate vicinity of Garth Hill, to warrant the conclusion of not only a denudation of the strata lifted up and broken between Garth and Tir y Cerrig, but also of a slide of the former hill some hundred yards to the south; notwithstanding this, normal lines from the present outcrops of the strata in accordance with the inclination, would pass through the position we may suppose the strata to have occupied subsequent to the anticlinal upheaval, and immediately anterior to the slide; the difference being, that its present position is one hundred yards lower down, or to the south on the line of dip, than it was preceding the avalanche. In applying the normal curve principle, in this instance, to arrive at the quantity of matter displaced from between, we should have an addition of one hundred yards of an immense thickness of measures which were never removed. We will suppose, for illustration, that there was no barrier to prevent the further progress of this avalanche towards the south, and that Garth subsided several miles to the south. The normal line or curve would still hold good, and there would be, in that case, an appearance of a denudation of the same thickness of strata for several miles in extent, whereas the actual quantity would not exceed a few hundred yards.

The consideration of a southerly movement of Garth

Hill, notwithstanding its limited extent, does not therefore appear to favor the normal curve principle, as a means in all cases, by which the quantity of matter removed by denudation can be ascertained, however applicable it may be considered in simple cases. The necessity, therefore, of an acquaintance with the direction taken by the anticlinals, and the different bearings of the pressures emanating therefrom on the stratification within their influence, evidently appears the more requisite. It will, however, here suffice to state, after what has been previously noticed with regard to the direction taken by the anticlinals in connection with the South Welsh Coal Field, and their effects on the measures, that the subsidences produced by them amounted in the aggregate to a perpendicular depth of 3,500 feet between the head of the Llynvi Valley and Penllergaer, 1,750 feet of which has been produced by the central anticlinal and the north lateral pressure, and 1,750 feet by the former and the south lateral pressure.

It will appear by this, that the central anticlinal, from its being south of the coal strata to the west of Baglan, afforded a protection to that extent (less the difference in surface elevation as before explained) of additional measures in that direction, whereas from its reaching a point in the Llynvi district, north of the transverse centre of the upper or Penllergaer series, the order of action became altered, and in some measure reversed, which it maintained to the River Taff, when it again gradually worked its way to the south in its eastern course.

This, from its passing north of the transverse centre of the Penllergaer series in the district between the head of the Llynvi valley and the River Taff, caused a slight

movement *en masse* to the south, whilst the lateral pressure of the north anticlinal was directed, as shown in the accompanying diagram, across the diagonal force, S, (the diagonal pressure acting in the direction, now the foot of the south rise of the measures in the south trough, from C to A, devastating the whole of the Penllergaer beds, which previously reposed on the Pennant series to the east of the Ton Mawr fault, and which from their elevated position, effected by the central anticlinal, H, became within its disintegrating influence. This, together with the gravity of the mass inclining southward, caused an intensity of force to be applied against the strata on the apex of the south lateral pressure, A, as to detach and annihilate the whole of the coal measures, down to the carboniferous limestone on that side of the Coal Field, or between the present basseting edge of the coal strata and the Bristol Channel. If we now consider a south wing of the lower series of coal strata to the south of the division effected by these forces to have been saved out of the wreck, the impulse given to it at the moment of action would, we should think, have caused it to descend over the surface of the carboniferous limestone, which presented a slight inclination to the south, (a con-

[Diagram, No. 8.]


A H C North, central and south anticlinal.
S Diagonal pressure between the central anticlinal and south lateral pressure.
P P P Strata disintegrated.

dition favorable for a descent in that direction,) until intercepted by some effectual barrier, and, as we have before observed, precisely on the same principle as a sliding avalanche descends over the mountain slopes into the valleys beneath.

If it be supposed (a supposition before stated that cannot be maintained) that any coal beds occupy a position under the waters of the Bristol Channel, is it not equally probable that they might have been forced into that depositary by the lateral pressures in the manner just described, on being separated from the mother mass, as of their being out-liers, and the continuity between denuded? By this admission, the normal curves, in accordance with the angle of dip, would represent a much greater quantity of matter removed than would have actually occurred.

The same may be said with respect to the coal field of the Forest of Dean. In this case ocular manifestations are obviously more in favour of a lateral subsidence, and of that coal field having been moved into its present position by the powerful lateral forces which acted upon it, when upheaved and detached from the larger mass by the Usk anticlinal, and which from its gravity, favoring a movement in that direction, caused a sliding avalanche of the entire series on that side of the division to take place, than of its being an out-lier, and the mass of matter which once filled up the void between, to have been removed or denuded. This is materially strengthened by the fact of the side opposite the one detached from the larger mass overlapping the mountain or carboniferous limestone, and that of several patches of coal measures in that quarter reposing on the old red sandstone, and in one or two instances resting on the silurian system.

That denudation took place to a very considerable extent is indubitable; but it is equally evident that it has been regulated by the direction of the anticlinals through the different series of stratification and the combined influence of the pressures emanating therefrom. Even in the South Welsh Coal Field, we find the central anticlinal to have reversed the order of its pressure on the mass in a distance of a few miles. To the west, in the locality of Swansea, it acted as a south lateral pressure on the coal measures, thus affording them a protection: but in the Llynvi district to the east, where it passed north of the transverse centre of the upper series, it turned the gravity of the whole of the coal measures to the south, which, with the other pressures, produced a devastation of materials of many hundred square miles in area, and of a thickness of upwards of 2,500 feet.

What then, let us ask, would be the consequence of two of those elevating forces, accompanied by their attendant lateral pressures, running parallel to each other through a considerable tract of country, one favoring a southerly and the other a northerly movement? The probability would be, a separation of the higher strata, forced by the opposite pressures into positions many miles apart. We cannot, surely, in cases of this description and which are very common, consider the void between to have been produced by denudation, in accordance with the normal curve theory. The view entertained of the measures in South Wales having been deposited thinning out from south to north, a greater amount of thickness having taken place on the south than on the north,—whereas this thinning out in the strata appears, in compliance with the angular theory, to have been effected by their subsequent exposure to

a greater amount of compression in that direction, when the anticlinals were formed, and which has been demonstrated in a former part of the work,—also militates against the denudation theory at present maintained by geologists. In many instances this thinning out of the strata takes place in an opposite direction, and, when such is the case, it is invariably followed by a diminution in the angle of dip: so universal is this rule, that we have not seen or heard of a single exception to it, but what could be satisfactorily accounted for as having arisen from some local disruption of the stratification. Indeed there is not a coal field in Europe, or any other part of the globe of which we possess information, wherein the strata do not shew a larger amount of total thickness on the side presenting the steepest inclination, save in cases where the angle of dip on every side exceeds 45°. This is rendered the more manifest, by the fact of the coal in the centre and on the side presenting the least inclination, being invariably harder and more compact than on the other.

Let us, in conclusion, suppose what would be the condition of the strata in the South Welsh Coal Field, if the central anticlinal had passed to the south of the present outcrops of the coal beds. We should, in that case, have the measures in the north trough, Llynvi, to the east of the Ton Mawr fault, 3,500 feet beneath their present elevation, and on a level with the same to the west of Swansea. Fortunately, this is not the case, and we find that the direction taken by the central anticlinal through the coal field to the east of Swansea, has been the means of uplifting the highest beds of coal to a height of 1,600 feet above the level of the sea, and yet the crowning bed at that elevation is 2,500 feet in geological position beneath

the highest stratum at Penllergaer, at a height of not more than 500 feet above the level of the sea. By restoring the beds in the north trough to the east of the Ton Mawr fault, equivalent to those which take ground to the west of Swansea, and which have been swept away by the lateral pressures, the mountains in that part of the coal field would present an elevation of upwards of 500 feet above Snowdon the highest mountain in Wales, and more than 1,500 feet above the present summit of the Brecknock Beacons. It is unnecessary for us, on this occasion, to enter into further particulars on this subject, as what has been already advanced will suffice to shew that it is the direction taken by the anticlinal levers, which determines the nature and extent of the denudation of any series or system of stratification.

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## THE STRUCTURAL FEATURES OF THE SOUTH WELSH COAL FIELD, AND THEIR RELATION TO THE STRUCTURAL FEATURES OF THE EARTH.

If we take a survey of the various systems, chains, and insulated mountains in different parts of the globe, we shall find them to present high peaks with gentle or steep declivities on either side, or with one side abrupt and rugged, and the other gradual and comparatively smooth; one system of mountains presenting a precipitous descent on one side, and another on the opposite. It frequently happens that the same chain has steep declivities in one district, and in the next, gentle and gradual slopes in the same direction. Malte Brun, in his Physical Geography,

gives the following description of mountain chains, &c. "Another general point of view in which mountains may be considered, is their position relatively to each other. Some are completely insulated, more particularly those of a volcanic origin; it is the same also with those of a calcareous nature, and some others. Both China and Ireland furnish many examples. The rock of Gibraltar and the fortress of Gwalior, in Hindostan, are of this description. We may also mention Mount Aornos, where a whole people supported a siege against Alexander. Mountains are seen most frequently in groups. Sometimes chains branch out from a common centre in angular directions. Sometimes the centre mass itself is a lofty chain, straight or curved, whence, at different periods, secondary chains have apparently been formed: the Alps may be placed in this class. Sometimes we see irregular groups of several chains, amongst which no one particular can be ranked as the principal: such are the collections of mountains in Asia Minor and Persia. But the most remarkable sort is that of long-connected chains which, like the Cordilleras of the Andes in South America, continue for hundreds and even thousands of leagues nearly in one direction, having on both sides regular layers or ranges of smaller mountains, but sending off very few secondary chains. These great chains evidently bear the stamp of the highest antiquity, and seem to have been the silent witnesses of the creation; it is upon their summits and their sides that we can read the history of the globe, in characters more distinctly defined than even those which the Alps and Pyrennees afford.

"In general, all the chains of mountains in the same continent seem to have a mutual connection, more or less apparent; they form a sort of frame-work to the land, and

appear in the origin of things, to have determined the shape it was to assume.

" Mountains, whether insulated or in groups, exhibit on both sides, declivities which are either gentle and long, or rapid and steep. We ought particularly to remark this general fact, that the greater number of the principal mountains have one of their sides very steep, and the other of a very gradual slope. The Alps, for example, are much more rapid on the Italian side, than on that of Switzerland. On the contrary, the Dophrines or Scandinavian Alps have a much steeper declivity to the west and north-west, than towards the south and east. The Pyrennees are steeper towards the south than the north; the mountains of the Asturias are the reverse; but those of the Sierra Morena, and particularly the Alpuxurras in Grenada, seem to be steepest and most abrupt towards the south. Mount Atlas and Mount Libanus present towards the Mediterranean bold and craggy declivities. But, with regard to the latter at least, it is certain that towards the Euphrates it is by no means steep. Mount Taurus (supposing it to terminate at the source of the Euphrates) exhibits two very different declivities; for in Caramania and Anatolia the descent is very abrupt towards the south, while there are some very extended upland-plains or plateaus towards the north; in Armenia, on the contrary, the declivity on the north side is very rapid. The Ghants on which the plateau of the Deccan in southern Hindostan rests, have precipitous declivities towards the west, and long and rather gentle slopes towards the east." Thus, there is no constant rule; every thing depends upon local circumstances.

If our attention be now turned to what has been pre-

viously stated relative to the anticlinals and subsidences of this coal field, particularly of the central anticlinal reversing the order of its pressure on a large proportion of the measures in a distance of a few miles; altering the physical features of the district through which it passed accordingly: producing in one locality, elevations gently sloping to the south, and in the next, steep declivities in the same direction, and also to the points of amalgamation of the central anticlinal and south lateral pressure in the Usk Valley on the east, and Carmarthen Bay on the west, where the strata of an under series have been uplifted through overlying beds into conical elevations, assimilating in appearance insulated cones of volcanic mountains, we shall have little difficulty in recognising in these, a striking resemblance to the outlines of those peaks, systems, and chains of mountains just described, and that therefore the movements which imparted to the whole this uniformity of structure, must have been governed by the same laws arising out of some common cause, and harmonising in all its results.

There is, however, a difference in the period, direction, intensity, and area of action of these movements. We shall, therefore, bring them under consideration accordingly. The primary or larger and the secondary or lesser movements: —The primary movements of elevation and subsidence were of an alternate character, and embraced within their sphere of action, extensive tracts, approaching in some instances to entire continents; whereas, the secondary were confined within one or other of these oscillating zones. As the elevating zone of these alternate movements of elevation and subsidence reached its maximum, the balance was reversed, and the elevating became the

subsiding zone; so that as the now zone of elevation approached its next maximum, which contained by this time a portion or the whole of a series of stratification deposited during subsidence, the pressure increased to such an extent, as to prevent the free circulation of the internal elements. These, in their efforts to escape, produced the anticlinals which now point out the direction taken by those powerful levers to the weakest point of resistance, or where two or more of them converged to a common centre or became united; when they combined together in a comparatively desperate struggle, to escape through the superimposing strata, which resulted either in success, followed by a volcanic eruption like that of Teneriffe, Bourbon, and others, or a failure, and effecting only a slight dome or cone-shaped elevation, like that to be observed in the Usk Valley, to the east of the South Welsh Coal Field. The anticlinals formed by these agents were necessarily accompanied by extensive dislocations, such as represented in diagram No. 6, which caused entire divisions in the mass, and which were accompanied by another movement of depression and elevation somewhat resembling the former; so that there appears to have been a wheel acting within a wheel, or a pair of scales of smaller size (comparatively) working or moving up and down, at the two extremities or ends of a pair of scales of larger dimensions.

The magnitude of the primary or larger movements may be, in some measure, inferred from the extent of the secondary, which we have designated the smaller scales (one of which, the Coal Field of South Wales might be considered to represent) moving up and down at either end or extremity of the larger.

In a former part of this treatise, we have shewn by demonstration, that the elevations and subsidences in the Coal Field of South Wales, in the district between Llynvi and Penllergaer, amounted in the aggregate, to about 3,500 feet. The upper tilestone, Llangeiner Mountain, is 1,600 feet above the level of the sea, and Penllergaer about 500 feet above the level of the same; but the upper tilestone of Llangeinor Mountain, which is near its summit, is geologically 3,000 feet in the measures (south rise) beneath the highest stratum at Penllergaer. If we restore the coal beds to their primeval, or the position they occupied on the primary movement reaching its maximum of elevation, and immediately anterior to the secondary which disintegrated the coal strata on the elevated side, the highest stratum at Penllergaer would be upwards of 2,500 feet above the level of the sea. Again, by replacing the measures which have been swept away from the elevated side to the east of the Ton Mawr fault, we should have an elevation above the level of the sea of upwards of 4,000 feet, or more than 500 feet higher than Snowdon, the highest mountain in Wales. This appears extraordinary, but such would be the case. It is not, therefore, incompatible to consider that the same law which effected this change, also determined the configuration of the different systems of mountains, and the several series of stratification composing them in the globe, and that hence arises the step-like gradation in their heights, from the lofty granite ridges down to the slightly-elevated hills of the coal formation.

There have been many hypotheses advanced relative to elevations and subsidences. Mr. Lyell considers it more than probable that the latter exceeded the former in extent. Mr. Darwin states, that continental elevation is the effect

of a general cause manifesting itself at particular points in greater intensity; as in experimental pressures on solids of every form, the weakest part alone yields to a force which, up to a certain point, was borne equally by all. This consideration Mr. Darwin has applied to the alternate bands of elevation and subsidence, which are inferred from his survey of modern coralligenous reefs and islands. In his generalization, it appears that the points of volcanic eruption are all full on bands of general elevation, where the uplifting force is at a maximum. This view tends to confirm the general probability of a refrigerating globe, and that the general condition on which all these phenomena of simultaneous elevation and subsidence may be made to depend, is a result strictly deducible from the hypothesis of a refrigerating globe.* Mr. Hopkins in his work on Terrestrial Magnetism, considers them to be vertical undulations subject to a horizontal movement *en masse* northward, amounting to at least ten seconds per annum, and that the dry land, as it approaches or reaches the north pole, becomes oxidated and reduced to its primary element, and that Great Britain and other countries which are situated in the same parallel, will disappear from the surface of the globe, and other more southerly lands will take their place.

That simultaneous or alternate elevations and depressions have taken place, and are still proceeding in different parts of the globe, is indubitable, from data furnished by persons resident where they have ensued and are now in motion. But that the real nature, extent, and the rela-

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* Phillip's Geology.

tion of the changes accompanying them are as yet undetermined, is quite manifest, from the circumstance of the three views or theories just adverted to being separately supported by evidence which gives to each of them a nearly equal shew of probability. The question, therefore, as to which of these (if either) is right, must remain unsettled until one or other of them is borne out by a definite and incontrovertible proof. As regards what has been herein advanced relative to the subsidences and elevations which have occurred in the South Welsh Coal Field, the case is different. We have put forward a theory supported by a demonstration, by which the elevations are found to be equal in extent to the subsidences, and which, therefore, assumes a higher degree of importance than it otherwise could have done. With respect to the hypothesis as to whether or not the subsidences of the primary movements exceeded in extent the elevations, we are as yet, in some degree, undecided; this may or may not have been the case. The examinations we have hitherto made, lead to the conclusion that they resemble, in some degree, a pair of weighing scales evenly suspended, set in motion, and after one or two movements up and down, as the case may be, to return back to their former position, and as the elevating sides reached their maximum of elevation, another series of movements ensued (secondary) from off the elevated side of which a large quantity of materials were devastated, which went towards the formation of the next system of stratification: thus gradually reducing the extreme circumference-curve of the globe, tantamount in its results to a solid crust reposing on a liquid nucleus, and subject to a gradual contraction, or in other words, to a slowly-refrigerating globe.

A section of the rocks composing the crust of the earth present the following order of succession, and the mountains the gradation in their heights. The primary slope from the side of granitic ridges,—the Granwacke and its transition beds lie between mountains of less elevation,—the coal formation, &c., occupy a position in basins flanked by hills still lower in the scale,—and the tertiary beneath those again, so that there are no less than four steps in the descending scale of elevation from the granite to the tertiary formation. It should be remembered, however, that these systems of rocks are not always found to occur following each other in complete succession as just represented. In many instances, parts and entire systems are wanting; but when such is the case, the physical features or scale of gradation in the heights of the mountains present a corresponding difference, and whatever number of beds or series of stratification are absent, those remaining never occur out of their order: that is, the carboniferous limestone is never found under the old red sandstone, or the Granwacke to repose on the old red sandstone; but when any bed or series is found missing, the next in the ascending scale takes its place: hence it is, that whatever number of beds may be present, they never occur out of their natural order of superposition.

Those who have paid attention to the aspects and geological structure of different countries are fully aware of the uniform arrangement of the following order of phenomena which present themselves. The mountains towering one above the other in regular succession, and the strata of which they are constituted becoming more decided and violent in their inclination in the same direction. By an examination of the stratification of Great Britain or any

other part of the globe (especially where the phenomena adverted to are most prominent), from the coal measures down to the granite, but ascending in point of elevation, and keeping in view the principles of elevation and subsidence (secondary) as explained in the preceding pages relative to the South Welsh Coal Field, there will be little difficulty in perceiving how these uniform features were produced. On reaching the next system of deposits in descending order from the coal measures, we are at once struck with the identity of changes which have ensued, the only distinction being in the extent which is exemplified by more extensive faults and a steeper inclination in the strata. Then in cases where there have been upwards of 2,500 feet swept from off the elevated side of the coal measures, &c. (like that in the South Welsh Coal Field), it would not be incompatible to consider the devastation of materials to be much greater in the next. The next series would present a still greater havoc, which is also borne out by the same criteria, and on planting ourselves on the granitic base, the wreck of matter would appear to be of an extent much easier conceived than described. Whether the pressures which cleaved the measures from the elevated side of the secondary movement of elevation and depression were sudden or gradual, would be difficult to determine; probably rather sudden, and took place at the time when the elevating zone of the primary movement reached its maximum. These were successively borne away towards the formation of the base of the next system in the ascending scale, the remainder being supplied from various sources by such means as are now proceeding around us (volcanic eruptions, denudation, and other causes), with this difference, that the agents by which the necessary materials were furnished for the superstruc-

ture of the older deposits, were more uniform and regular than those in operation at the present time. The latter, on the return of the primary movement to its next maximum of elevation, presented, according to circumstances, a part or an entire series of stratification deposited during subsidence, was subjected to the same law of disintegration as the former; so on until the several systems of deposits composing the crust of the earth were formed. Hence arises the step-like gradation to be observed in the heights of the mountains, and the gradual diminution in the inclination of the strata of which they are constituted, from the lofty granitic ridges down to the tertiary formation. After what has just been explained relative to the secondary pressures, it will be readily perceived how the reduction in the circumference-curve of the earth ensued, without a diminution in volume. As the disintegration of the strata by the secondary pressures on the elevating side of the primary movement reaching its maximum of elevation, must have materially altered the configuration of the primary mountains, and also reduced the radius of the extreme circumference-curve of the earth, or the utter limits of its primary periphery.

This offers a ready solution to our finding systems of deposits absent in one geological zone, and their presence in the next, as the subsiding side could only have been the zone of re-formation whilst the other furnished the materials, and that of our finding corresponding fossils in strata of a distinct character, or systems of formation; as in cases where two zones of deposition took place at the same time or in the same epoch, one in Europe and the other in Africa. The one being supplied from a district with any series of stratification absent, and the other from

a zone where it was present, the appearance and composition of the deposits would present a corresponding disparity, but the fossils precisely the same, unless it may be supposed that the climates of the epoch were very unequal, and that some distinction might have arisen therefrom.

It is unnecessary for us, in this instance, to prolong our observations on this theory, as what has been already advanced will suffice to show its import, and that there is scarcely a subject in geology to which it does not offer a clear and satisfactory explanation. We would, however, observe in conclusion, that if it were within the means of the reader (one possessing a knowledge of geology) to plant himself on the shores of the Indian Ocean, and to pass onwards from thence through the plains of Hindostan to the pinnacles of the highest mountains in the interior: then to proceed and do the same on the continent of America, from the Atlantic across the Appalachian chain to the Pacific side of the Rocky Mountains, bearing in mind the while the theory herein put forward, and to note during his route the relative connection of the volcanic peaks to those continents: afterwards to take Europe from the Mediterranean Sea across the central chain to the Northern Ocean: in the next place to come nearer home, and traverse the island of Great Britain from the south-eastern coast of England to the north-western shores of Wales, and to terminate his researches by an examination of the South Welsh Coal Field, we feel convinced that the result of his investigations would lead him to acknowledge, that at every stage in his progress he saw the theory written in large and unmistakeable characters in the structural features of the districts surrounding him, and that the South Welsh Coal Field presented a correct represen-

tation of the physical structure* of the stratified deposits constituting the crust of the earth, and that, therefore, any theory which may be supposed to be applicable to that coal field, would necessarily adapt itself to the whole.†

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* The hills and mountains in Boloachistan and other parts of India have their stratifications forced into anticlinals, with faults running parallel to them, extending in some cases for upwards of one hundred miles in the same direction, and in others for only short distances. These have altered the structural character of the districts accordingly, in one part producing steep declivities on one side, and in another in the opposite direction. The anticlinals and faults in connection with the Appalachian chain of hills on the continent of America, present a corresponding arrangement. The structural features of the Alps and other mountains in Europe have been governed by the same law. Great Britain, particularly North and South Wales, complies in the altered condition of its strata with the former, and the South Welsh Coal Field presents, in its anticlinals, faults, and subsidences, a similar arrangement. It is, therefore, quite obvious that the whole has been governed by the same law, the result of some common cause, uniform in all its effects.

† Humboldt states in his "Cosmos," that after repeated trials, he found the lowest coal strata in the Saarbruck coal field to be upwards of 20,000 feet below the level of the sea. On applying the angular theory to this field of coal, the depth of the lowest coal strata is reduced to about 13,000 feet beneath the level of the same, or nearly 7,000 feet less than the depth given by Humboldt. On extending the principles of this theory still further, we find by a rough computation, which is, notwithstanding, near the truth, the thickness of the stratified deposits composing the crust of the earth to be about 34,500 feet, or nearly one-fourth the difference between the polar and equatorial diameter of our planet; that is, the perpendicular depth from the surface stratum down to the granitic crust in any part of the globe, does not exceed that depth: hence, the deepest point in the ocean, and the summit of the highest mountains, could not have been at any time more than that number of feet beneath and above the level of the sea. This computation leads to the inference that the perpendicular distance from the summit of the highest mountains down to the deepest point

in the ocean, must have been at some remote period about 69,000 feet, or nearly one-half the difference between the polar and equatorial diameter of the earth.

This is certainly remarkable, especially when it is considered that the density of dry land is nearly 2 4-5ths that of water, and the waters of the ocean, &c., about 2 4-5ths greater in bulk than the dry land, one balancing the other, as it were, the greater capacity of one compensating for the greater density of the other.

This, with other manifestations, especially what we have previously remarked relative to the depressions and elevations in the Coal Field of South Wales (secondary), brings us to the conclusion, that the depressions and elevations which the crust of the earth has suffered, from the granite to the tertiary formation, have been produced by a transference of pressure from one zone of deposition on to the next,—that is, the deposits of one zone have been upheaved, a portion of which was disintegrated and transferred towards the formation of the next—and that these movements are either increasing or decreasing, and will, if they have not already done so, reach the smallest value, when they will commence a fresh series in a new or opposite direction, in the same order as the planets, or remain at rest.

As it is ascertained that the planets proceed from a minimum to a maximum and vice versa, the probability is, that the depressions and elevations in the earth are regulated by the same law, and if it should be supposed that these movements are now becoming less and less in magnitude, it is more than probable that they will, on reaching the smallest value, commence to increase in extent for the next maximum. It would appear, therefore, that the elevations and depressions have or do not proceed in the mannner generally maintained by geologists; but on the contrary, resemble that of a pair of scales evenly suspended, set in motion, and after a series of oscillations above and below the plane of suspension, to return to the same level. This leads us to infer that the temperature at the surface of the earth suffered no very material alteration from the crystalline aggregate, (granite,) to the tertiary formation, and that the lowest depth at which plants are entombed in the stratification, is about 16,000 feet below the level of the sea, or at about the same depth below, as the line of perpetual snow is at the present time above the level of the same at the equator. This depth would embrace the upper beds of the Silurian system in the Welsh zone, and corresponds with the facts to be observed in that

series of deposits, the first traces of fossilized plants appearing at the close of the Silurian beds. In other zones the case would be different, as it would depend on the number of systems of stratification present, so that, in some instances, plants would be found entombed in beds, reposing on the granite, lithologically different to the Silurian, yet deposited at the same time or in the same geological age.

The planets are subject to the influence of two disturbances, emanating, it is said, from their reciprocal attractions. "One is termed the periodic and the other secular. Periodic perturbations are said to be compensated when the bodies return to the same relative position with regard to one another and the sun. The secular are compensated when the orbits return to the same position relatively to one another, and the plane of the ecliptic. Planetary motions, including both these kinds of disturbances, may be represented by a body revolving in an ellipse, and making small and transient deviations, now on one side of its path and now on the other, whilst the ellipse itself is slowly but perpetually changing, both in form and position. In fact, they oscillate between zero and unity, and when the variations accumulate to a maximum by slow changes in however long a time, they decrease by the same slow changes till they arrive at the smallest value, again to begin a new course." — *Mrs. Somerville's Physical Sciences.*

This appears to be the case with the elevations and depressions which affect and have affected the stratification of the earth. It is probable, therefore, that a reciprocal connection exists between the eccentricities, the motions of the apsides, &c., and the elevations and depressions of our planet; hence, a change in one is followed by a change in the others, and what is perhaps remarkable, the mean depth of the stratified deposits composing the crust of the earth (that is, the thickness of the different systems of stratification in their deposited condition), taken separately and prior to their subjection to the pressures of the anticlinal levers, from the surface down to the granite, would be something less than 40,000 feet, or about as many feet as it would take of years for the earth's orbit to become a circle, according to the present decrease, which is assumed to be forty miles annually. Indeed, there appears to be every reason to consider that the earth is slowly but constantly changing its position in every respect, and that, in a long period of time it effects a movement equivalent to a revolution (perpendicular to its daily revolution from west to east) proceeding from west to north, and as this movement progresses, a proportionate

alteration is produced in its configuration, so that the present polar or lesser axis will, at some remote period, become the equatorial or larger axis, the deposits disintegrated from the larger will be distributed and transferred towards the swelling out of the lesser or present polar axis, so on from phase to phase. We need not, therefore, be surprised at finding tropical plants entombed in the stratification of the northern regions, &c.

The whole force which disturbs a planet is equal to three partial forces: a radius vector or radial force, a perpendicular, and tangential force. These forces act on the planets in precisely the same manner as those which have thrown the strata composing the crust of the earth out of their deposited condition, into the form or position we now find them. The radius vector, the perpendicular or upheaving force—the perpendicular, the diagonal—and the tangential, the lateral pressure which swept or sweeps a portion of the strata from one zone of deposition on to the next. It would appear, therefore, that each system of deposits, (that is, the deposits of each movement of elevation and depression,) possessed or possesses its own independent anticlinals and system of volcanic action, which, from the nature of the pressures, range more or less parallel. The seat of one system of volcanic action being beneath the surface of the granite (primary), and the seat or focus of other systems in the stratified deposits,—and therefore above the granite. The former, the result of a transference of pressure, and acting on much the same principle as that of a forcing pump, and the latter the result of a transference of deposits giving rise to two powerfully-opposed pressures generating a third power, electricity, which formed the anticlinal ridges in its passage to the weakest point of resistance, where it either broke through the superincumbent strata, followed by a volcanic eruption, or a failure, and effecting only an elevation in the form of a dome, like that to be observed in the Usk Valley to the east of the South Welsh Coal Field.

Kepler's law relative to the planetary motion is, that equal areas are described in equal times, to accomplish which the velocity of the planets cannot be uniform. There are, however, manifestations which lead us to infer that the movements of the planets are uniform, and that the apparent irregularity may be probably attributed to a zig-zag or angular motion, now on one side of its path and now on the other, whilst the ellipse itself is changing both in form and position, and producing an effect tantamount to an irregular velocity; and when it is

## FORMATION OF COAL.

There are few subjects within the range of geological science on which so many hypotheses have been advanced as that of the formation of coal; and the question as it at present stands, appears far from being satisfactorily determined. It has been, from time to time, attributed with nearly an equal show of probability, to the three kingdoms of nature,—animal, mineral, and vegetable. It is now, however, admitted by nearly all to be of vegetable origin. Mr. Horner, in his opening address as President

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considered that each system of stratification from the granite to the tertiary formation, has in its turn passed from a primary or deposited thickness to that of a minimum and maximum, the mean of which gives the primary value or thickness, the connection and identity of the changes taking place in the earth, and its motion in space, as well as that of the other planetary bodies, become the more manifest. Here then is unity and harmony! How grand, yet how simple! The same inherent actuating force or principle which regulates the formation and re-formation of terrestrial matter through its numerously-multiplied phases uniformly extending its influence into the boundless depths of infinite space.

We have entered thus far into this enquiry in order to shew the mutual dependence which appears to exist between the changes which have, and are at the present time taking place in the earth, and its motion in space, &c., &c.

Sixteen hundred feet beneath the level of the sea, the lowest depth at which fossilized plants are entombed in the stratification, in compliance with what we have herein advanced, should not be regarded as the thickness of the same deposits on either basseting edge or outcrop, as such would give, in many instances, about one-third more, or upwards of 20,000 feet.—*See* APPENDIX.

of the Geological Society thus sums up the latest views on the formation of this valuable deposit:—

"It is scarcely possible to visit a coal field, or to read the description of one, without being led to theorise on its mode of formation. The origin of coal has long been a subject of great difficulty; nor has any theory been yet advanced with which it has been possible to reconcile all the appearances which the coal-measures exhibit, all the variety of forms in which coal is found. Indeed the more closely we examine the phenomena, the more do we feel the distance we are from a satisfactory explanation of them. According to some geologists, coal-seams and their accompanying strata are accumulations of land-plants and stony detritus, carried down by rivers into estuaries, and deposited in the sea, where the vegetable matter undergoes changes that convert it into coal. Others are of opinion that coal is the altered residuum of trees and smaller plants, that have grown on the spot where we now find them; that the forests were submerged and covered by detrital matter, which was upraised to form a foundation and a soil for another forest to be in its turn submerged and converted into coal, and that thus the alternations which the vertical section of a coal-field exhibits are to be accounted for.

"In the gealogical works of the last year, we find the former theory maintained by Sir R. Murchison as most generally applicable; Mr. Lyell is more inclined to adopt the latter. Sir R. Murchison dwells upon the facts of the alternations of coal with limestones containing marine remains, which are so frequently met with in most countries where coal-fields prevail; and as a striking instance of this, he refers to the Donetz coal field. A remarkable example

of a similar kind, occurring in Maryland, is mentioned by Mr. Lyell. At Frostburg, a black shale, ten or twelve feet thick, full of marine shells, rests on a seam of coal about three feet thick, and 300 feet below the principal seam of coal in that place. The shells are referable to no less than seventeen species, and some of them are identical with, and almost all the rest have a near affinity to, species found in the Glasgow and other coal measures.

" The theory which refers the coal to trees and plants which have grown on the spot where it now rests, is illustrated by Mr. Lyell by observations he made in Nova Scotia, on the south shore of the Bay of Fundy, at a place called ' The Joggins.' He states that there is a range of perpendicular cliffs, composed of regular coal measures, inclined at an angle between twenty-four and thirty degrees, whose united thickness is between four and five miles. About nineteen seams of coal occur in the series, and they vary from two inches to four feet in thickness. The beds are quite undisturbed, save that they have been bodily moved from the horizontal position in which they must have been deposited to that inclination they now have. In these coal beds, at more than ten distinct levels, are stems of trees, in positions at right angles to the planes of stratifications; that is, which must have stood upright when the coal measures were horizontal. No part of the original plant is preserved except the bark, which forms a coating of bituminous coal, the interior being a solid cylinder of sand and clay, without traces of organic structure, as is usually the case with sigillaria, and like the upright trees in the coal measures cut through by the Bolton railway. The trees, or rather the remains of stems of trees broken off at different heights above the root, vary

in height from six to twenty-five feet, and in diameter from fourteen inches to four feet. There are no appearances of roots, but some of the trees enlarge at the bottom. They rest upon, and appear to have grown in, the mass which now constitutes the coal seams and under-lying shale, never intersecting a superior layer of coal, and never terminating downwards out of the coal or shale from which the stem rises. The underclay or shale often contains stigmariæ. Here, then, he states, are the remains of more than ten forests, which grew the one over the other, but at distant intervals, during which each, from the lowest upwards, was successively covered by layers of great thickness, of clays and solid stone, the materials of which must have been arranged and consolidated under the surface of water, and the vegetation of every layer in which the upright trees are fixed must have grown on land.

" The formation of coal measures like the above, and of all others where there is evidence that the vegetable matter was not drifted to the place it now occupies, but must have grown on the spot, is then accounted for by supposing that the land sank below the level of adjoining water; that gravel, sand, and mud, were washed down from the land that did not sink, and formed layers of clay and sandstone over the submerged forest, either in sufficient quantity to rise to the surface of the water, and form land for the next forest, which was submerged in its turn, or that a contrary internal movement took place, which again raised the submerged land; and that for every seam of coal, one above the other, a similar series of changes must have taken place. It is to this oscillatory movement that Mr. Lyell ascribes the formation of the above remarkable phenomena in the Bay of Fundy, and others of a like nature.

" At first sight, both theories seem well founded, when applied to the particular coal fields described; and it is possible that these eminent and experienced geologists may be of opinion that both are true, as applied to different situations. But I see great difficulties to the full acceptance of either in many of the phenomena which, on a close examination, we find coal fields generally present." Mr. Horner then refers to several recently-published sections of coal fields. One in South Wales presents eighty-four seams of coal from one inch to nine feet thick, alternating with 340 beds of sandstone, slate, and clay. In this case, the group of coal-bearing strata is a mile in thickness. A coal field in Nova Scotia is of twice this thickness, and contains seventy-six coal seams. Mixed with the latter are a few limestones containing bivalve shells. The learned president then proceeds—

" Throughout the whole 7,000 feet in the South Wales section, and if the limestones are, as is most probable, of fresh-water origin, also throughout the 14,570 feet in the Nova Scotia section, there appears no trace of any substance of a marine character; and from anything exhibited in the composition of the beds, all might have been deposited in fresh water. It seems infinitely improbable, had the deposition taken place in the sea, that a series of accumulations of this description, implying, be it observed, a vast duration of time, with different depths and different qualities of sea-bottoms, should have taken place without a trace being discoverable, either upon the surface of the submerged layers of vegetable matter, or in any part of the clays and sandstones that lie upon them, of a marine animal or plant. It seems no less improbable that, in a sea-skirting shore, there should be such an absence of

agitation throughout so vast a space of time, as to allow a tranquil deposit of layers of fine detritus over a wide area, a spreading out of the leaves of delicate plants in layers of clay and sand like the specimens in a herbarium, and a gradual and insensible passage, in many instances, from one bed into another. Great as the North American lakes are, I am not prepared to say that grave objections may not be urged against the probable existence of such vast bodies of fresh water as would be of sufficient extent and depth to receive the beds of many coal fields; but the absence of marine remains throughout vast depths of strata in coal fields is a remarkable fact, well deserving the most careful investigation.

" That the terrestrial vegetable matter from which coal has been formed has in very many instances been deposited in the sea, is unquestionable, from their alternations with limestones containing marine remains. Such deposits and alternations in an estuary at the mouth of a great river are conceivable, but whether such enormous beds of limestones with the corals and molluscs which they contain, could be formed in an estuary, may admit of doubt. But it is not so easy to conceive the very distinct separation of the coal and the stony matter, if formed of drifted materials brought into the bay by a river. It has been said that the vegetable matter is brought down at intervals, in freshets, in masses matted together, like the rafts in the Mississippi. But there could not be masses of matted vegetable matter of uniform thickness 14,000 square miles in extent, like the Brownsville bed on the Ohio: and freshets bring down gravel, and sand, and mud, as well as plants and trees. They must occur several times a-year in every river: but many years must have elapsed during the gradual deposit

of the sandstones and shales that separate the seams of coal. Humboldt tells us (Kosmos, p. 295) that in the forest lands of the temperate zone, the carbon contained in the trees on a given surface would not, on an average of a hundred years, form a layer over that surface more than seven lines in thickness. If this be a well-ascertained fact, what an enormous accumulation of vegetable matter must be required to form a coal-seam of even moderate dimensions! It is extremely improbable that the vegetable matter brought down by rivers could fall to the bottom of the sea in clear unmixed layers; it would form a confused mass with stones, sand, and mud. Again, how difficult to conceive, how extremely improbable in such circumstances, is the preservation of delicate plants, spread out with the most perfect arrangement of their parts, uninjured by the rude action of rapid streams and currents carrying gravel and sand, and branches and trunks of trees!

"In the theory which accounts for the formation of beds of coal by supposing that they are the remains of trees and other plants that grew on the spot where the coal now exists, that the land was submerged to admit of the covering of sandstones or shale being deposited, and again elevated so that the sandstone or shale might become the subsoil of a new growth, to be again submerged, and this process repeated as often as there are seams of coal in the series—these are the demands on our assent of a most startling kind. In the sections above examined, we have eighty-four seams of coal in the one, and seventy-six in the other. In the Saarbruck coal field there are one hundred and twenty seams, without taking into account the thinner seams, those less than a foot thick. The materials of each of these seams, however thin (and there are some not an

inch thick, lying upon and covered by great depths of sandstones and shales), must, according to this theory, have grown on land, and the covering of each must have been deposited under water. There must have heen an equal number of successive upward and downward movements, and these so gentle, such soft heavings, as not to break the continuity or disturb the parallelism of horizontal lines spread over hundreds of square miles; and the movements must, moreover, have been so nicely adjusted, that they should always be downward when a layer of vegetable matter was to be covered up; and in the upward movements, the motion must always have ceased so soon as the last layers of sand or shale had reached the surface, to be immediately covered by the fresh vegetable growth; for otherwise, we should have found evidence, in the series of successive deposits, of some being furrowed, broken up, or covered with pebbles or other detrital matter of land, long exposed to the waves breaking on a shore, and meteoric agencies. These conditions, which seem to be inseparable from the theory in question, it would be difficult to find anything analogous to in any other case of changes in the relative level of sea and land with which we are acquainted."

These views on the formation of coal have been materially strengthened by the researches of Mr. Whitham, who states, that, on polishing thin slices of coal, he found the vegetable tissues of plants distinctly marked in it. That lignite is composed of vegetable matter is now considered by geologists to be established; we shall, therefore, leave that out of our present enquiries. There are, however, circumstances connected with the composition of coal of the independent coal formation which render the preceding

hypothesis very unsatisfactory, notwithstanding the result of Mr. Whitham's experiments. If coal were formed from land plants drifted and deposited in the sea, or from the altered residuum of trees, and smaller plants grown on the spot where we now find it, as explained in Mr. Horner's address; how is it that the fossils so profusely distributed amongst the accompanying beds are never found in the coal itself, and that the interior of these fossils are invariably filled with sandstone, or some other matter finer in its granulation than that in which they are imbedded? These are phenomena which cannot be reconciled with either of the preceding views, as if coal were formed from plants and trees drifted and deposited, or grown on the spot where we now find it; such would certainly imply that, in some instances, the fossils would be met with in that deposit, and the interior of those found in the accompanying strata would present a corresponding grain to that in which they were imbedded. If we again ask ourselves the question, whence comes the almost unlimited quantities of bituminous matter found distributed in all its varieties amongst the different stratifications composing the crust of the earth, and the bituminous oils which are seen exuding in vast quantities from the fissures and bassets of beds of rocks or formations, in which there is not a single impression of a terrestrial plant to be met with, and, in many instances, prevailing in districts where terrestrial vegetation, even a single blade of grass, is wholly unknown? the subject is rendered still more unsatisfactory: indeed, the farther our investigations extend in the matter, the more remote does the hypothesis appear, of coal being entirely composed of vegetable matter.

A purely-accidental circumstance which occurred under

our notice some little time back, has materially strengthened a view we have long entertained relative to the formation of coal, and appears in connection with the theory of elevation and subsidence explained in the preceding chapter, to offer a more compatible explanation than any hitherto given, of the origin or formation of that valuable deposit.

From an open cutting worked through ground of the description known to Welsh miners as Tyr-biw or quick ground, there flowed a stream of water holding in suspension a considerable proportion of an heterogeneous mixture of sand, clay, and other matter. The stream at some little distance from the cutting passed into a small reservoir, in which there gradually collected on the surface of the water a thin coating of a dark bituminous substance. As we were observing this collection, the stream brought down with it a sprig of wood, which, on reaching the coating of bitumen, stopped suddenly, and almost at the same instant there passed from it streams or lines of electricity, which separated the coating into squares and parallelograms. This occurred six or seven times in quick succession with about a second intermission between each shock; and what appeared equally remarkable, this same sprig of wood after the discontinuance of the electric shocks, was seen moving up and down in the water, appearing as if the bitumen repelled it and prevented it from rising to the surface, so that it was compelled to float about between the bottom and the coating of bitumen until it subsided.

We examined the sprig of wood immediately after it had subsided to the bottom, and, to our surprise, found that the bark or cuticle, which was stained or covered by a thin film

of bituminous matter, could be pressed together between the fingers, and that the solid properties of the interior had disappeared, and were substituted by a small portion of fine sand.

Fresh sprigs of wood were subsequently placed in the stream, and in each case the same results ensued. It at once occurred to us that the circumstance of the bitumen floating on the surface of the water repelling the sprigs of wood from it, after the solid properties of their interior had passed away, thus keeping them in suspension at some little distance beneath it, until the necessary quantity of finer debris had been introduced into the vacuums to compel them to subside to the bottom, afforded a clear solution to our not finding fossils in the coal itself, and of their interior being filled with matter of finer composition than that in which they are imbedded. The striking resemblance of the parallelograms and squares into which the coating of bitumen was separated by the streams and lines of electricity, to the splits and cutters in the coal and its accompanying beds, particularly those of the upper or red-ash series, led us to infer that the agents or agent which produced the one effected the other also: and that coal instead of being derived from plants either drifted and buried in vast quantities amongst the debris at the bottoms of lakes, estuaries, and lagoons, or grown on the spot where we now find it, was formed on the surface of water and composed of an heterogeneous mixture of bituminous matter abstracted from the three kingdoms of nature,—animal, mineral, and vegetable.

By supposing one of these alternate movements of elevation and subsidence adverted to in the preceding chapter

to be in motion on the continent of India or America, there would be little difficulty in perceiving how the formation of coal took place;—the subsiding or side of re-formation to embrace within its limits extensive lagoons and estuaries, into which flowed rivers like the Mississipi, Ganges, and others, holding in suspension a large proportion of an heterogeneous debris derived from the mineral, animal, and vegetable kingdoms;—this on reaching the estuaries to find means of separating;—the mud, sand, and heavier portions subsiding in accordance with their gravity to the bottom, and the bitumen and lighter matter rising to the surface; and as the trees and plants which were brought down by the rivers passed into the bituminous collection taking place on the surface of the waters in the estuaries, they became electrified and thereby deprived of their interior properties, which mixed with that on the surface, and which afterwards combined in repelling and keeping those trees and plants floating about in the waters at some distance beneath. The hollow cuticles or cylindrical cavities of these trees and plants proved convenient receptacles for the finer debris. This, in proportion to the quantity introduced, increased their gravity, and ultimately compelled them to subside to the bottom, where they were buried in the beds then forming; hence it is that we do not find fossils in the coal itself, and their interior invariably filled with matter finer in its composition than that in which they are imbedded. The bituminous collection taking place on the surface of the water increased incessantly, and on reaching a certain thickness and necessary density, also subsided and bore down before it the plants and cuticles of plants held in suspension by the water between it and the deposit then forming at the bottom. These, in proportion to their quantities, converted a part

of the deposit on which they reposed, or with which they came in contact, into a bed of carbonaceous earth of the description now forming the substratum of nearly every bed of coal, and known as fire-clay, pouncing, &c., &c. To this may be ascribed the reason of our finding fossils in greater abundance in these beds than in any other in the coal measures, and that of many coal fields presenting no traces of marine remains* above the lowest bed of coal, as the subsidence of the first bed would annihilate them.

As the bed of bituminous collection reached the bottom it was immediately covered by the debris, and at the same time a fresh deposit began forming on the surface of the water in the estuary. This in its turn subsided, so on until the hundred beds of coal were formed, or until the primary movement was reversed, and the mass subjected to the secondary pressures. The time† elapsed be-

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* The presence of marine remains found imbedded in strata above the lowest bed of coal (as is the case in some coal fields) would imply migration in the interval between the deposition of the coal beds.

† Sir George Staunton infers, from experiments made on the quantity of sediment brought down by the Hoang-Ho River in China, that it is capable of converting a square mile of one hundred and twenty feet in depth into solid land in the course of seventy days. According to this calculation, a river holding in suspension an equal quantity of sediment to that of the Hoang-Ho would, in little more than two hundred years, furnish the necessary amount of matter to form beds of clay, shale, rock, &c., of one hundred and twenty feet in depth over the whole area occupied by the coal measures in the South Welsh coal field, which is about 700,000 acres. Again, three rivers separately holding in suspension three times the amount of matter as the Hoang-Ho, would, in less than three thousand years, supply the necessary materials to construct the whole of that superstructure of mineral wealth.

tween the formation of two beds of coal, would depend on the quantity of debris furnished by the rivers feeding the estuaries or lagoons, and the amount of earthy matter amalgamating with the bituminous collection taking place on the surface of the water, as its density would increase in proportion to the quantity of earthy matter introduced into its composition; so that, in some cases, a bed of only a few inches thick, would become so increased in gravity, by the introduction of a considerable proportion of sand, &c., as to be obliged to subside, whereas, in other instances it would reach a thickness of nearly as many feet. This is probably the cause of the difference in the thickness of the coal beds and their accompanying strata, and also that of the thin beds of coal, yielding, in most cases, on analysis, a larger proportion of earthy residuum than the thicker; indeed, the natural conditions arising out of this arrangement in the order of deposition corresponds in every particular with those to be observed in the coal measures, and there is not a single phenomenon connected with the formation of coal, to which this theory does not offer a ready solution.

### CHANGE FROM BITUMINOUS TO ANTHRACITE.

There are ample manifestations to assume that the difference in the quality of the coal of the South Welsh Coal Field was produced by the pressures it was subjected to when the anticlinals bounding and intersecting it were formed; indeed, we have ocular demonstration of the fact, inasmuch as actual features presenting themselves under precisely the same circumstances, may warrant such a conclusion. If a line be drawn across the Coal Field

from the south outcrop (Llanharry), to the north outcrop (vicinity of Hirwain), the following difference in the quality of the coal is to be remarked. At Llanharry, on the south outcrop of the south trough, the coal is soft and friable, and the angle of dip about 40°. In the centre, where the strata are nearly horizontal, it is hard and compact. Rising north, at an angle of more than 40°, to the apex of the central anticlinal by Collenna, the coal is soft and friable, and similar in quality as at Llanharry, where it rises to the south outcrop at nearly the same angle. On the apex of the anticlinal, where the strata are nearly horizontal, and within a distance of less than one hundred yards to the soft and friable coal, the same beds are hard and compact. On the north outcrop (vicinity of Hirwain) where the lower measures present themselves, and which, from their position suffered the greatest amount of compression, and rising to the outcrop at an angle of about 12°, the coal is free-burning—a stage between bituminous and anthracite, containing an insufficiency of bitumen to be ranked bituminous, and a per centage of carbon under that of anthracite.

The following tables of the difference to be observed in the quality of the coal in various parts of the coal field from Monmouthshire to near Llanelly, in Carmarthenshire, will perhaps render the subject more intelligible, than by following out the previous mode of explanation.

MONMOUTHSHIRE, AND EAST OF THE RIVER TAFF. BITUMINOUS, HARD AND COMPACT, SAVE ON THE SOUTH RISE OF THE SOUTH TROUGH.

A section across the coal field from Llanharry,

south outcrop, to the vicinity of Hirwain, north outcrop.

| Locality. | Angle of dip. | Quality of coal. |
|---|---|---|
| Llanharry south outcrop | 40° | bituminous, soft & friable |
| Centre of south outcrop | horizontal or nearly | ditto, hard and compact |
| North rise anticlinal | 40° | ditto, soft and friable |
| North outcrop, (Hirwain) | 12° | free-burning |

A section across the south trough, Llynvi district:

| Locality. | Angle of dip. | Quality of coal. |
|---|---|---|
| South outcrop Park Tyrgunter | from 30° to 45° | bituminous, soft & friable |
| Centre of south trough, Llynvi valley | nearly horizontal | ditto, hard and compact |
| Anticlinal rise (north rise) | 10° | ditto, hard and tolerably compact |

A section across the north trough, from Baglan near the apex of the central anticlinal to the north outcrop.

| Locality. | Angle of dip. | Quality of coal. |
|---|---|---|
| Baglan anticlinal rise | 40° | bituminous, soft & friable |
| Centre of trough north of Neath Abbey Works | nearly horizontal | Free-burning, slightly bituminous |
| North outcrop | 13° | Anthracite, (upper beds free-burning, one insulated patch with upper beds bituminous. |

A section across the coal field, from the south outcrop to the west of Swansea, through Penllergaer to the north outcrop. The whole of the coal measures in this section are embraced by the lateral pressures, one north and one south of the outcrops, with two dependent or local saddle-backs. It is, in fact, a continuation of the north trough, the central anticlinal of the eastern district, becoming the south lateral pressure in this.

| Locality. | Angle of dip. | Quality of coal. |
|---|---|---|
| Cline district, south rise | ..from 30° to 40° | bituminous, soft & friable |
| Centre of trough Penllergaer | nearly horizontal | Free-burning, some of the upper beds inclining to bituminous. |
| North outcrop..... | average 13° | anthracite |

This line of section is west of all the anticlinal faults in the coal field, which can be considered to effect any important alteration in the coal measures, although it might be inferred from the increase in the angle of dip at Llanelly, that another of some magnitude has ensued between that place and Penllergaer; but it is more than probable that this increase of inclination to the west has arisen from the interception of the longitudinal dislocation, running parellel to the centre of the trough in this district, by a local transverse or trough fault, effected by increased pressure emanating from the amalgation of the central anticlinal and south lateral pressure in Carmarthen Bay, west of the western promontory of the peninsula of Gower: indeed, the fact of the old red sandstone protruding through the carboniferous limestone on that promontory, adjoining the embouchure of Llochwr River, in the same manner as we find an under series to have been forced up through the old red sandstone, where these two forces unite in the Usk Valley some sixty miles to the east, renders the consideration, particularly in conjunction with the winding southward of the carboniferous limestone on the opposite coast (Pembrokeshire), that these two forces acted so powerfully on the measures in Carmarthen Bay, as to produce an elevation equivalent in this case to an anticlinal of an extent nearly equal to the transverse limits of the coal strata. This detached the whole of the coal measures in Carmarthen Bay, and caused them to rise to and fall from this local transverse elevation east and west,

thereby placing the coal measures under the waters of that bay (contrary to the view entertained) in a favourable position for working from either side. There can be no difficulty, therefore, in conceiving, that as this transverse elevation of the coal measures took place, on the same principle as the elevation produced where these two forces unite in the Usk Valley some sixty miles to the east, a corresponding depression to have ensued, and effecting a trough fault to the east, which cut off the longitudinal dislocation, and caused the increase in the angle of dip. We have, therefore, no grounds to assume that any anticlinal faults have occurred west of Penllergaer, consequently, as the inclination is somewhat greater west than east of Llochwr, the deepest part of the South Welsh Coal Field may be considered to be at a point in the immediate vicinity of Llanelly, and west of this last down-throw-west trough fault.

Finally we would observe, that as the north lateral and these united pressures neared each other to the west in Pembrokeshire, the distance between them became so very limited as to cause, in some degree, two diametrically opposite movements, one passing above the other*; the north lateral pressure compressing and in some measure forcing the carboniferous limestone and old red sandstone

* These opposite movements accompanied, as they must have been, by intense pressure, overcoming every hostile resistance by the production of faults which, of necessity, generated friction, and which again, in its turn, gave rise to powerful elements. These, from the conflicting nature of the forces, were distributed throughout the entire mass, and deprived the whole or nearly the whole of the coal beds of their bituminous properties.

to the south, whilst the south lateral pressure occasioned the coal measure to slide over and repose on the silurian system to the north and north-west*.

It can hardly be questioned but that the tables (p. 147) of the difference in the quality of the coal in different parts of the coal field, manifestly imply that the change has been produced by the direction and intensity of the pressures emanating from the anticlinals; whether sudden or gradual in their operations, would be difficult to determine.

The line of division separating the soft and friable from the hard and compact coal in the south trough, from the River Taff to near Aberavon, is in the direction taken by the maximum of diagonal pressure between the central anticlinal and south lateral pressure, now the foot of the dip of the measures from the south outcrop and at right angles thereto. All above or to the south of this diagonal line being soft and friable, and all to the north (with one or two exceptions) hard and compact, thus evidently shewing that the measures underwent a greater amount of compression to the north than to the south of the diagonal line, between the central and south anticlinal. On the anticlinal rise near Collenna, where the strata present an angle of dip of upwards of 40°, the coal beds are soft and friable, and surrounded, as it were, by the same beds

* Professor Ramsey attributes the circumstance of the coal measures reposing on the silurian system in Pembrokeshire, to have arisen from a fading away of the forces which may have acted with greater intensity in other places.

in either a nearly horizontal position or inclining slightly, in a hard and compact state. It is, therefore, quite obvious that the difference in the quality of coal, in this instance, was produced or regulated by the amount of pressure it was subjected to, and the fact of the soft and friable coal being confined to the division of the beds which present the steepest inclination, clearly indicates the nature and direction of that pressure.

The line of division separating the soft and friable bituminous coal from the free-burning and anthracite in the north trough, from the embouchure of Llochwr River to the Ton Mawr fault, east of the town of Neath, is also at right angles to the strike of the strata from the apex of the central anticlinal, but as this anticlinal passes to the south of the outcrop of the coal beds west of Swansea, we must consider the division in that district at right angles to the strike of the measures from the south outcrop. All to the south of the diagonal line being soft and friable bituminous coal, and all to the north (with a few exceptions) free-burning and anthracite. As free-burning is merely a stage between bituminous and anthracite coal, the diagonal line of division may be considered to separate the bituminous from anthracite.

Then, as the division between the soft and friable and hard and compact coal is diagonal or nearly so to a square of the mass between the central anticlinal and south lateral pressure in the south trough, that is, a diagonal of a square of the coal measures between the central and south anticlinal would be nearly in the direction of the foot of the south rise of the strata, we are in a great degree justified in assuming the still further change into anthracite

in the north trough (where a similar line separates the bituminous from the anthracite coal, especially as this metamorphosis really appears to the west of the first subsidence, giving rise to any important increase in number and entire thickness in the coal measures) to have been effected by a more intense pressure accompanied by extensive dislocations which together generated friction, while that in its turn set the internal elements (probably electricity) in operation on the mass, forcing the bitumen or volatile matter, in a state of gas or otherwise, through its pores, overcoming every resisting opponent in its course; indeed, the greater the resistance the more fierce would become the agent, which increased in proportion to the accumulation of pressure of friction, and leaving behind it the traces only of a once primeval bituminous existence in the tarry lustre of the anthracite. In every fault, and on nearly every crop of coal, &c., in the coal field, there is to be observed what is aptly termed by Welsh miners *tir llosg* (burnt ground), presenting an appearance of having been subjected to the all-but-spent influence of some powerful internal element. As we proceed upwards in the mass of coal measures on the eastern, southern, and northern edges of the coal field, where the coal is bituminous, it appears more lavishly charged with bitumen, the Pennant containing more than the lower or lina beds, the upper or Mynyddyslwyn still more than the Pennant; thus obviously manifesting that the coal has been deprived of its bitumen or volatile matter, in proportion to the amount of pressure and friction it was exposed to, as the larger the mass the greater the excitement, and the more powerful were the internal batteries in their operations.

In conclusion, we would draw the reader's attention to

the circumstance of the features herein explained (the increase in the thickness of the measures in the same proportion as the increase in the angle of dip, or *vice versa*—the subsidences—the principles or cause of denudation—the reduction of the extreme circumference-curve of the earth equivalent to a liquid nucleus supporting a solid crust, gradually contracting in volume —the formation of coal—the cause of the soft and friable quality of coal in one part of the coal field, and the hard and compact in another—the still further change of the same to free-burning, and as pressure and friction increased its complete conversion into stone coal or anthracite) being resolvable to the same common origin, the centres or source from whence emanates the agent which sets the internal elements or element in operation, by which the solid structure of our planet is regulated, from the selection and arrangement of the minutest atom of matter to the critical catastrophe of a volcanic eruption; and if it should be supposed (of which, we believe, there can be little doubt) that the power induced by the action of the tidal wave operates in such manner on the electric fluid as to keep it in a state of perpetual excitement, it would readily be perceived from the propensity of that powerful agent to increase in intensity in proportion to the accumulation of pressure and friction, that no barrier, however great, could resist its restoring the equilibrium; and those who have experienced the tremor accompanying a disastrous earthquake will not hesitate to concede, that the highest mountains would yield submissively to its will: yet, however terrific the consequences, the changes effected are ever found to be in strict accordance with a law unerring and harmonising in all its results.

Arnott says, " we have learned enough to perceive that the great universe is as simple and harmonious as it is immense, and that the Creator, instead of interposing separately or miraculously, in the common sense of the word, has willed that all should proceed according to a few general laws, which laws He allows men to discover as knowledge advances and necessity requires for the better regulation of their concerns through life."

Is it then incompatible with our views, in the present stage of knowledge, to anticipate the time to be near at hand when we shall be able to reduce the science of geology into the form of a general theory, by which every phenomenon in connection with it can be resolved with a comparative degree of accuracy, as men can now calculate eclipses backwards and forwards for thousands of years, without erring a single beat of a pendulum?

ERRATA.

p. 38, last line of note, For " £1,000" read " £10,000."
p. 39, line 3, After " and" insert " make."
p. 43, line 11, For " molecule" read " atom."
p. 47, Instead of the Note, read " This fault is occasionally intercepted by transverse dislocations, by which it is shifted north and south of its general direction; in one instance the shift is considerable."
p. 70, line 6, For " is" read " are."
p. 71, line 6, For " diverging" read " taking place."
p. 99, line 4, For " positions" read " portions."
p. 99, line 8, Omit " and abrading influences."
p. 108, line 20, For " change of position in the angle of inclination," read " change of dip or inclination."
In various parts of the work the word " strike" has been used as synonymous with " dip."

# APPENDIX.

Page 132.—We stated that the coal strata in the Saarbruck coal field were, in compliance with the angular theory, about 13,000 feet beneath the level of the sea. We also find that the coal strata of the Huanoco field are about 12,800 feet above the level of the same. The depth, therefore, of the lowest coal strata beneath the level of the sea, corresponds with the elevation of the highest coal strata above the same level. This, together with what has been previously advanced relative to the depressions and elevations of the coal measures in the South Welsh Coal Field render it almost certain that the elevations have or do not exceed the depressions in extent.

The major axis of the dry land in our hemisphere appears to be about south-west and north-east. Did the lateral pressure from the north pole effect, in the present condition of the earth, an extreme protuberance near and in the line of the equator, we should have an excess in the equatorial radius over that of the polar of about 87,000 feet; this multiplied by 2 gives 174,000 feet, or nearly 34 miles, and equal to the extreme excess of the equatorial diameter over that of the polar.

An examination of a map of the globe would at once convince us that the before-named excess in the line of the equator has been altered considerably. Our calculations, therefore, must be modified in order to arrive at its present figure and dimensions. It has been stated in a preceding page, that the depressions were equal to 34,500 feet beneath the level of the sea; this deducted from 174,000 feet, leaves 139,500 feet, or something more than 26 miles, and equal to the present extent of the equatorial diameter over that of the polar.

This is merely an approximation; yet, from its near agreement with the computation given by Sir J. Herschel, we are in some measure disposed to consider it near the truth.

The means at present used in measuring the earth must, from various causes, be necessarily attended with uncertain results. The following data might probably be of assistance to those who may be engaged in that important task.

| | FEET | Excess of equatorial diameter. FEET |
|---|---|---|
| Extreme protuberance of the equatorial radius over that of the polar in our hemisphere ..... | 87,000 x 2 = | 174,000 |
| Deposited thickness of the stratified deposits from the surface down to the granite, and prior to their subjection to the anticlinal pressures, 39,000 feet by 2..... | 78,000 x 2 = | 156,000 |
| Present perpendicular depth from the surface down to the granite in any part of the globe, 34,500 feet and under by 2 ..... | 69,000 x 2 = | 138,000 |
| REVERSED. | | |
| Present thickness of the strata from the surface in the centre of any trough down to the granite, 34,500 feet and under by 2.. | 69,000 x 2 = | 138,000 |
| Deposited thickness of the same from the surface to the granite, 39,000 feet and under by 2 ..... | 78,000 x 2 = | 156,000 |
| Present thickness of the strata on the outcrops (south side) in the line of the equator, 43,500 feet and under by 2. This depth represents a section perpendicular to the dip of the strata from the south outcrops | 87,000 x 2 = | 174,000 |
| Extreme excess of equatorial diameter ..... | | 174,000 |
| From the surface to the granite perpendicular to the plane of the strata in the centre of any trough....(and under) | | 34,500 |
| Present excess of equatorial diameter ..... | | 139,500 |

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